Lecture Notes in Electrical Engineering 313

Tarek Sobh
Khaled Elleithy
Editors

Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering

Springer

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ISSN 1876-1100 ISSN 1876-1119 (electronic)
ISBN 978-3-319-06772-8 ISBN 978-3-319-06773-5 (eBook)
DOI 10.1007/978-3-319-06773-5
Springer Cham Heidelberg New York Dordrecht London

Library of Congress Control Number: 2014953842

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

This book includes the proceedings of the International Joint Conferences on Computer, Information, and Systems Sciences, and Engineering (CISSE 2012 and selected papers of CISSE 2013). The proceedings are a set of rigorously reviewed world-class manuscripts presenting the state of international practice in Innovative Algorithms and Techniques in Automation, Industrial Electronics, and Telecommunications.

CISSE 2012 is a high-caliber platform consists of four research conferences that were conducted entirely online. CISSE 2012 received 100 paper submissions and the final program included 55 accepted papers from more than 80 countries, representing the six continents. Each paper received at least three reviews, and authors were required to address review comments prior to presentation and publication.

Conducting CISSE online presented a number of unique advantages, as follows:

- All communications between the authors, reviewers, and conference organizing committee were done online, which permitted a short 6 week period from the paper submission deadline to the beginning of the conference.
- PowerPoint presentations and final paper manuscripts were available to registrants for 3 weeks prior to the start of the conference.
- The conference platform allowed live presentations by several presenters from different locations, with the audio and PowerPoint transmitted to attendees throughout the internet, even on dial up connections. Attendees were able to ask both audio and written questions in a chat room format, and presenters could mark up their slides as they deem fit.
- The live audio presentations were also recorded and distributed to participants along with the PowerPoints presentations and paper manuscripts within the conference DVD.

The conference organizers and we are confident that you will find the papers included in this volume interesting and useful. We believe that technology will continue to infuse education thus enriching the educational experience of both students and teachers.

Bridgeport, CT, USA — Tarek Sobh
Bridgeport, CT, USA — Khaled Elleithy
April 2014

Acknowledgments

The 2012 International Joint Conferences on Computer, Information, and Systems Sciences, and Engineering (CISSE 2012) and the resulting proceedings could not have been organized without the assistance of a large number of individuals. CISSE was founded by Professors Tarek Sobh and Khaled Elleithy in 2005, and they set up mechanisms that put it into action. Andrew Rosca wrote the software that allowed conference management and interaction between the authors and reviewers online. Mr. Tudor Rosca managed the online conference presentation system and was instrumental in ensuring that the event met the highest professional standards. We also want to acknowledge the roles played by Sarosh Patel and Ms. Susan Kristie, our technical and administrative support team.

We would like to express our thanks to Prof. Toshio Fukuda, Chair of the International Advisory Committee, and the members of Technical Program Committees.

The excellent contributions of the authors made this world-class document possible. Each paper received two to four reviews. The reviewers worked tirelessly under a tight schedule and their important work is gratefully appreciated.

April 2014

Contents

Performance Improvement in Public Administrations by Organizational Learning 1
Margareth Stoll and Dietmar Laner

From Information Security Management to Enterprise Risk Management 9
Margareth Stoll

Information System Engineering Promotes Enterprise Risk Management 17
Margareth Stoll and Dietmar Laner

Simulation Study on the Performance of Reactive and Position-Based Routing Protocols in MANET 25
Khaldoon Al-Shouiliy, Raed Alsaqour, and Mueen Uddin

A New Approach for Buffer Queueing Evaluation Under Network Flows with Multi-scale Characteristics 31
Jeferson Wilian de Godoy Stênico and Lee Luan Ling

Polynomial Compensation of Odd Symmetric Nonlinear Actuators via Neural Network Modeling and Neural Network Describing Function 39
O. Kuljaca, K. Horvat, J. Gadewadikar, and B. Tare

Stream Collision Management in MIMO Ad-Hoc Network Sustaining the Lower Bound of QoS 47
Viktor Zaharov, Angel Lambertt, and Olena Polyanska

On Query-Based Search of Possible Design Flaws of SQL Databases 53
Erki Eessaar

An Architecture for Mobile Context Services 61
Chad Williams and Jisna Mathew

An Actuated Tail Increases Rapid Acceleration Manoeuvres in Quadruped Robots 69
Amir Patel and M. Braae

PlantsVN: An User-Friendly Software for Creating and Managing Personal Plant Database and for Plant Family Identification 77
Nguyen Van Sinh

An Automated Tool to Support the Software Design Process 85
Fernando Uceda-Ponga and Gerardo Ayala-San Martin

A Low-Cost Force Measurement Solution Applicable for Robotic Grippers 95
R.V. Sharan and G.C. Onwubolu

Analyzing Operating Systems' Behavior to Crafted Packets 99
Thusith Abeykoon, Kasun Abeykoon, and Tirthankar Ghosh

An Access Control Model for a Grid Environment Employing Security-as-a-Service Approach 103
E.K. Olatunji, M.O. Adigun, and E. Jembere

Comparison of Collaborative-Filtering Techniques for Small-Scale Student Performance Prediction Task 111
Štefan Pero and Tomáš Horváth

Career Center System Software Architecture 117
Taner Arsan, Safa Çimenli, and Erhan Güneş

Mobile Camera Source Identification with SVD 123
A.-R. Soobhany, K.P. Lam, P. Fletcher, and D.J. Collins

Comparison of Manual and Image Processing Methods of End-Milling Burr Measurement 133
R.V. Sharan and G.C. Onwubolu

Automatic Image Annotation for Description of Urban and Outdoor Scenes 139
Claudia Cruz-Perez, Oleg Starostenko, Vicente Alarcon-Aquino, and Jorge Rodriguez-Asomoza

Autonomous Mapping and Navigation Through Utilization of Edge-Based Optical Flow and Time-to-Collision 149
Madhu Krishnan, Mike Wu, Young H. Kang, and Sarah Lee

NS2IT: Simplification of Computer Network Simulation 159
Martin Nagy and Peter Magula

Survey on Decentralized Modular Robots and Control Platforms 165
Tamer AbuKhalil, Tarek Sobh, and Madhav Patil

Utilising Fuzzy Rough Set Based on Mutual Information Decreasing Method for Feature Reduction in an Image Retrieval System 177
Maryam Shahabi Lotfabadi, Mohd Fairuz Shiratuddin, and Kok Wai Wong

IR-UWB with Multiple-Access Differential Detection Receiver 185
Walid Mahmoud

Digital System for the Study of Fast Processes 193
Florin Grofu and Constantin Cercel

A Location-Based Movie Advisor Application for Android Devices 199
Taner Arsan, Aykut Çayır, Hande Nur Umur, Tuğçe Güney, and Büke Panya

Eye Tracking and Head Movements Detection to Assist People with Disabilities: Unveiled 209
Amer Al-Rahayfeh and Miad Faezipour

A Comparative Study of Simulation Based Performance Evaluation of Routing Protocol for Ad-Hoc Networks 215
Ola Alsaqour, Raed Alsaqour, Tariq Alahdal, Rashid Saeed, and Mohammed Al-Hubaishi

Vulnerability Studies of E2E Voting Systems 223
Lauretha Rura, Biju Issac, and Manas Haldar

Reliability Assessment of an Intelligent Approach to Corporate Sustainability Report Analysis 233
Amir Mohammad Shahi, Biju Issac, and Jashua Rajesh Modapothala

Ubiquitous Text Transfer Using Sound a Zero-Infrastructure Alternative for Simple Text Communication 241
Kuruvilla Mathew and Biju Issac

Web Based Testing in Science Education 247
M. Hostovecky, M. Misut, and K. Pribilova

Determination of Optimal Hyper- and Multispectral Image Channels by Spectral Fractal Structure 255
Veronika Kozma-Bognár and József Berke

ICT as a Mean for Enhancing Flexibility and Quality of Mathematical Subjects Teaching 263
Mária Mišútová and Martin Mišút

Efficient High-Level Coding in a PLC to FPGA Translation and Implementation Flow 269
Christoforos Economakos and George Economakos

Modeling a Cold Rolling Mill for Optimization 277
Meshack M. Nzioki

Technological Development in Therapeutic Applications of Alternating Electric Fields: Review 287
S. Talele

Multi-Touch Gesture Recognition Using Feature Extraction 291
Francisco R. Ortega, Naphtali Rishe, Armando Barreto, Fatemeh Abyarjoo, and Malek Adjouadi

Model Driven Testing for Cloud Computing 297
Jéssica Oliveira, Denivaldo Lopes, Zair Abdelouahab, Daniela Claro, and Slimane Hammoudi

Implementing a Sensor Fusion Algorithm for 3D Orientation Detection with Inertial/Magnetic Sensors 305
Fatemeh Abyarjoo, Armando Barreto, Jonathan Cofino, and Francisco R. Ortega

Introducing Problem-Based Learning in a Joint Masters Degree: Offshoring Information Technologies 311
Vincent Ribaud and Philippe Saliou

Composition of Learning Routes Using Automatic Planning and Web Semantics 321
Ingrid-Durley Torres and Jaime Alberto Guzmán-Luna

A Novel Dual-Error Approach to System Identification 329
H. Greeff

On Verification of the Software Development Process 339
Deniss Kumlander

Control-Flow Checking Using Binary Encoded Software Signatures 345
H. Severínová, J. Abaffy, and T. Krajčovič

Transformation of the Software Testing Glossary into a Browsable Concept Map 349
Guntis Arnicans and Uldis Straujums

Metallographic Image Processing Tools Using Mathematica Manipulate 357
Sara McCaslin and Adarsh Kesireddy

Using Mathematica to Accurately Approximate the Percent Area of Grains and Phases in Digital Metallographic Images 365
Adarsh Kesireddy and Sara McCaslin

Real-Time Indexing of Complex Data Streams 371
Petr Chmelar, Michal Drozd, Michal Sebek, and Jaroslav Zendulka

Self-Organized Teams: A Contradictory Technique to Motivate Personnel 379
Deniss Kumlander

Pre-MEGa: A Proposed Framework for the Design and Evaluation of Preschoolers' Mobile Educational Games 385
Laila Shoukry, Christian Sturm, and Galal H. Galal-Edeen

A Review on Three Dimensional Facial Averaging for the Assessment of Orthodontic Disorders 391
Syed M.S. Islam, Mithran S. Goonewardene, and Mauro Farella

Reducing Stereotypes of Women in Technology Through Analysis of Videogame Blog Entries 399
Reva Freedman and Georgia Brown

Improving Student Learning While Converting a Computer Architecture Course to Online Format 405
Reva Freedman

Bioclimatic Modelling: A Machine Learning Perspective 413
Maumita Bhattacharya

nFTP: An Approach to Improve Performance of FTP Protocol on the Virtual Network Environment in the Same Physical Host 423
Nguyen Tan Cam, Huynh Van Tho, Nguyen Hoang Sang, and Cao Dang Tan

Hardware Architecture Review of Swarm Robotics System: Self Reconfigurability, Self Reassembly and Self Replication 433
Madhav Patil, Tamer Abukhalil, Sarosh Patel, and Tarek Sobh

Internet and Transdisciplinary Based Teamwork Formula for Elaborating a Bachelor's or a Master's Thesis 445
Liciniu A. Kovács and Mihai F. Talpoş

A Dynamic Pricing Algorithm for Super Scheduling of Computational Grid 453
Reihaneh Bazoubandi and Fatemeh Abdoli

A Comparative Analysis of Bayesian Nonparametric Inference Algorithms for Acoustic Modeling in Speech Recognition 461
John Steinberg, Amir Harati, and Joseph Picone

Requirements Based Estimation Approach for System Engineering Projects 467
Radek Silhavy, Petr Silhavy, and Zdenka Prokopova

Improvement of the Time Calculation of Cloud Radiance of One Atmosphere by the Method TDMAP 473
Bouya Diop, Adoum M. Moussa, and Abdou K. Farota

Process of Transformation, Storage and Data Analysis for Data Mart Enlargement 477
Zdenka Prokopova, Petr Silhavy, and Radek Silhavy

Exact Algorithm for Matrix-Based Multilevel Project Planning Problems 487
Zsolt T. Kosztyán

Operation of a Microgrid System with Distributed Energy Resources and Storage 495
Linfeng Zhang, Xingguo Xiong, and Junling Hu

The SOC Estimation of a Lead Acid Rechargeable Battery 503
Linfeng Zhang and Xingguo Xiong

Fast Computation of Frobenius Map Iterates in Optimal Extension Fields 509
Walid Mahmoud

Product Owner Responsibilities in the Project Assurance Process: Bridging Uncertainties Gaps 515
D. Kumlander

Micro Design and Value Analysis. The Selection of the Material for Die 521
Florin Chichernea and Ana Veţeleanu

The Internet of Things in Community Safety and Crime Prevention for South Africa 531
Nomusa Dlodlo, Paul Mbecke, Mofolo Mofolo, and Martin Mhlanga

Research Trends in Existing Technologies that are Building Blocks to the Internet of Things 539
Nomusa Dlodlo, Mofolo Mofolo, Lionel Masoane, Stanley Mncwabe, George Sibiya, and Lawrence Mboweni

Efficient Partitioning and Allocation of Data for Workload Queries 549
Annamaria V. Kish, John R. Rose, and Csilla Farkas

Toward the Automatic Construction of Strategic Plans Based on Ontologies 557
Liliana Ibeth Barbosa-Santillán, José Pablo Nuño-de-la-Parra, Juan Jaime Sánchez-Escobar, and Carlos Arturo Vega-Lebrun

E-Learning Environments: Actor Network Theoretic Inspirations into Localized Discovery 565
Ashoka Jayawardena

Educational Tools: A Review of Interfaces of Mobile-Augmented Reality (mAR) Applications 569
Siti Salmi Jamali, Mohd Fairuz Shiratuddin, and Kok Wai Wong

Automatic Extraction of Relationships Among Software Patterns 575
Asma Hachemi and Mohamed Ahmed-Nacer

Smart Email: Almost An Agent Platform 581
Magdalena Godlewska and Bogdan Wiszniewski

Improving Trace Analysis Using Ontologies for Hardware Resourcing 591
Manuel Corona-Pérez, Gerardo Padilla-Zárate,
and Liliana Ibeth Barbosa Santillán

An Energy Efficient Self-healing Mechanism for Long Life
Wireless Sensor Networks 599
Dame Diongue and Ousmane Thiare

Novel Steganography over HTML Code 607
Ammar Odeh, Khaled Elleithy, Miad Faezipour, and Eman Abdelfattah

Secure Cost Effective M-Learning Through Cloud Computing 613
K. Kartheeban and M. Venkatesulu

A Multi-Level Privacy Scheme for Securing Data
in a Cloud Environment 623
Ezekiel K. Olatunji, Matthew O. Adigun, and Paul Tarwireyi

Performance Improvement in Public Administrations by Organizational Learning

Margareth Stoll and Dietmar Laner

Abstract

Due to increased pressure for cost reduction and performance in public administrations and the growing requirements for optimized service quality, citizens orientation and effectiveness public administrations must improve always faster their services and organizations. They must elaborate or interpret, communicate, learn, use and continuously change and improve a lot of legal requirements, regulations, procedures, directives, forms and checklists. Thus, the management of appropriate regulations (relevant laws, directives, procedures, forms and checklists) is fundamental and key challenge for public management. Nevertheless, regulations are distributed commonly IT supported and the collaborators have great difficulty to find appropriate, actual regulations. They are hardly used as reference for solving ad hoc learning needs. In addition, change proposals, new ideas or questions are usually not related to the existing. Consequently, new regulations are often created as add-on. They can become in contradiction to the existing. Based on Foucault's theory we structure all regulations in accordance to the ISO 9001 standard for quality management, prepare them accordingly didactical principles and publish them on an organizational learning system. This innovative work-place integrated organizational learning concept is best supported by a confidence-based open corporate culture. The results of our case studies in different medium-sized administrations suggest that the concept was useful to promote practice-oriented regulations, workplace integrated need-oriented learning and the continual performance improvement of the public administrations.

Keywords

Document management • Need oriented learning • Public management • Knowledge management • Quality management • Organizational development

Introduction

Starting Situation

Due to the increased pressure for cost reduction and performance in public administrations and the growing requirements for optimized service quality, citizens' orientation, transparency and effectiveness the public administrations must improve always faster their services and organization in accordance to citizens' and legal requirements. Legal requirements and their interpretations

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_1,

by using business process documentation, procedures, directives, forms and checklists (further called regulations) must be changed in increasingly shorter cycles. Thus, the continual improvement by knowledge generation based on individual learning and the management of information, data, knowledge, laws and regulations has become key challenge and a completely new role.

In this respect, the effective management and exploitation of data, information, laws and regulations for knowledge creation and learning are central for modern public management. Yet, the existing IT systems, which support the daily work of the knowledge worker, have not kept pace with the evolving complexity and diversity of challenges facing knowledge workers [1–4]. Thus, the service-oriented knowledge management and work integrated access to relevant data, information, knowledge, laws and their interpretation by using regulations has become a key topic of general interest [1, 3–7].

Standard based management systems, such as ISO 9001 [8] for quality management, are increasingly more implemented in public administrations. They offer a clear structure and require a systematic approach for the establishment, distribution and use of the entire documentation of all administrations' processes (business processes) including all correlated documents and procedures. In addition the processes and related documentation must be continually controlled and improved accordingly established processes.

Purpose of the Article

Legal requirements and their interpretations by internal regulations are distributed in public administrations commonly on paper or electronically by intranet, email, social media or document management systems. In this way the collaborators read the regulations once when they are distributed, but they are scarcely used for solving ad hoc job problems. The distribution and retrieval of regulations and information are great challenges for public administrations. Questions or change proposal are mostly not related to existing regulations. The improvement of organizational performance is isolated from existing regulations. Consequently new regulations can become in contradiction to the existing. In addition the number of regulations is growing more and more. Their complexity is increased.

Research Approach

The theoretical work of Michel Foucault explains the influence of the individual and the knowledge (regulations, technology) on common practice (power) and the continual improvement of organizational performance [9]. Based on Foucault's theory we structure the internal regulations in accordance to ISO 9001, prepare them regarding constructivist didactic theory and use an extended constructivist learning platform as organizational learning system [3, 6, 7] for the distribution of the regulations. This concept was implemented and tested in different medium sized public administrations. The case study results were collected by established process and system measurement methods and by interviewing the managers and collaborators.

Structure of the Article

Firstly we describe based on the starting situation the project objectives (section "Purpose of the Article") and present the main requirements of ISO 9001 (section "Research Approach"). After we explain our approach (section "Structure of the Article") for the establishment of the regulations (section "Development of the Regulations"), the didactical preparation of the regulations (section "Didactical Preparation"), explain the requirements for the organizational learning system (section "Learning System Requirements") and close this section with the introduction and use of the constructivist organizational learning system (section "Introduction and Use"). We report the project experiences and results of the implementation in different public administrations (section "Project Experience and Results"). Finally the achievement of the project objectives (section "Achieving the Project Objectives"), the success factors (section "Success Factors") and cost and benefits (section "Costs and Benefits") are discussed. At the end we give an outlook (section "Outlook") and conclude (section "Conclusion").

Project Objectives

How the internal regulations can be prepared systematically and stored well structured in order to promote practice oriented regulations, need-oriented access for the collaborators and continual performance improvement of the public administrations?

By preparing the regulations in accordance to Foucault's theories [9], ISO 9001 [8] and constructivist didactical principles and by implementing it on an organizational learning system, which is an extended constructivist learning system (see section "Learning System Requirements") we expect to foster:

- need-oriented, workplace and process integrated access to the regulations for learning and
- organizational performance improvement,
- by employee involvement and knowledge sharing,

Fig. 1 Main requirements of standard based management systems

- practice-oriented regulations and
- shorter initial training periods for new collaborators.

In that way the public administration will be promoted in achieving all their objectives. Performance and the fulfillment of citizens' and legal requirements will be improved.

Main Requirements of ISO 9001

ISO 9001 and all other standards for management systems are based on common principles [8, 10] (see Fig. 1):

- Organizations objectives and strategies must be established regarding all interested parties (internal and external stakeholders).
- All processes including the management/governance process, service processes, support processes, resource processes and optimization processes must be defined and optimized in accordance to the established objectives.
- Process oriented resource management must be promoted including human resource development, IT—management and the management of other relevant infrastructures, tools and instruments.
- The organization and their objectives and strategies must be continually optimized in accordance to the established processes in sense of a PDCA cycle (plan, do, check/study, act).

The established management system must be structured and systematically documented. It must be communicated within the organization and the collaborators must be continually motivated for using the system and for recommending improvements.

Approach

Development of the Regulations

Firstly all regulations must be elaborated. Considering the needs and expectations of all interested parties we establish the organization policy with consistent objectives, priorities and strategies [11]. All offered services and their processes are analyzed bottom up by interviewing the collaborators involved and by integrating knowledge management. Thereby the responsible function, the underlying laws, their interpretations by regulations, the applied documents, checklists, forms, IT applications and other tools and necessary infrastructures are studied for all processes and activities.

Afterwards the services and their applied processes with related documents are optimized to fulfill the established objectives, performance/effectiveness, citizen orientation, service quality, efficiency and legal compliance. In accordance to the established corporate objectives we consider all relevant aspects, such as performance, quality, data protection, information security, human resource development, information management, data protection, environmental management and eco-sustainability, societal management, health and safety management, communication, knowledge management, IT-systems and others [11].

In addition the necessary resources, tools, instruments and required trainings for achieving the objectives and for improving the administration (e.g. human resource development, IT—management, maintenance, facility management) are analyzed, optimized and documented (Fig. 2).

Afterwards the monitoring and optimization processes are established and implemented to improve continually the performance of the public administration. Thereby the knowledge generation, representation, communication and acquisition processes are structured, systematically planned and documented [1, 5, 7].

The entire regulations must correspond with lived processes [12]. They must be structured in accordance to ISO 9001 [8].

Didactical Preparation

After the development, the regulations must be prepared regarding didactical principles [13]. To support need-oriented work-integrated learning the way for accessing the single modules must be as short as possible. Based on constructivist theory we prepare the regulations practice oriented. All needs and expectations of the collaborators are analyzed and considered as early as possible [7, 12, 14].

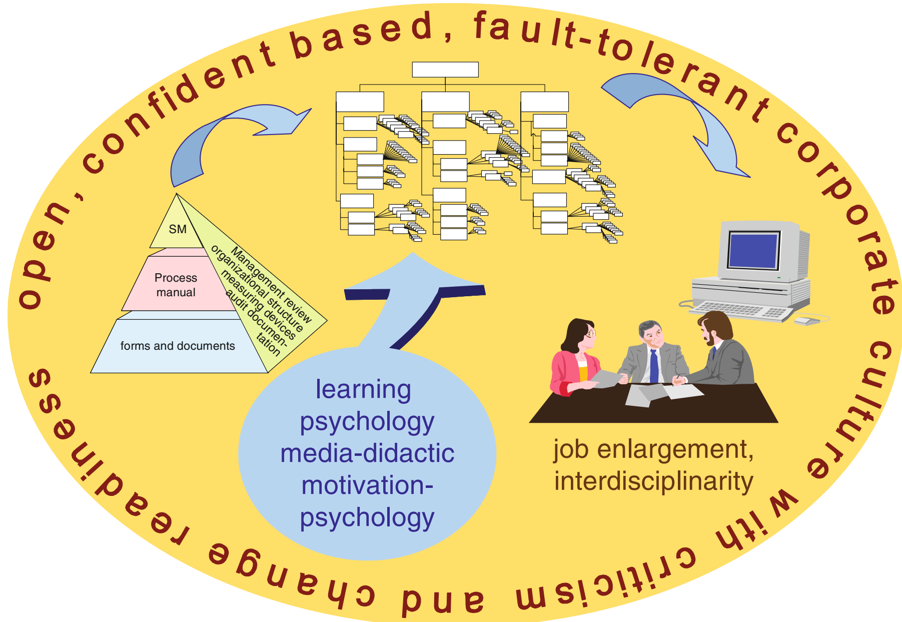

Fig. 2 Approach for need oriented regulations' access

They demand overall an efficient and effective search function and a clear structured system.

Thus the whole content is divided into small modules, typecasted and functionally well structured. We offer an effective index and different start assistances (for example, for new collaborators, department oriented, management oriented, topics referred, based on the standard and others). Apart from the self-driven learning approach, the system offers guided learning for new collaborators or for collaborators with little IT or learn competences.

After appropriate editing, the regulations are published on the organizational learning system. The upload function should be user-friendly, simple and intuitive to handle supported by as large didactical support as possible. In accordance to the constructivist theory the proposed approach requires the possibility to link different regulations or sections of regulations with media formats, objects and all parts of contained graphics and pictures.

Learning System Requirements

Based on literature research, the requirements of standard based management systems and the interviews of collaborators and management an organizational learning system demands additional to the general requirements of learning systems, following particular characteristics:

- It must be simple and intuitive to handle. It must provide the possibility to use different views of (or links to) the same object, different start facilities, comfortable search functions, filtering of content using object types, simple uploads of content and links to external literature. It must promote individual learning by personal bookmarks, annotations, summaries and notes, as well as glossary, FAQs, etc.. . . [1, 5, 7, 14, 15].
- It must offer secure context-sensitive communication (discussion forum, chat) to all elements, as well as newsgroups, wiki, newsletters and whiteboards. It must support knowledge distribution, collective knowledge generation and collective learning [1, 5, 15, 16].
- Uploading and the administration of new content must be simple with as large didactical and media pedagogic support as possible [6]. There must be the possibility to insert, annotate and discuss context sensitive the content of most different documents and media formats (such as text, graphic, table, picture, sound records, video). Also creativity tools should be integrated [6].
- Due to legal requirements we need the administration of access rights, the support of the change process, versioning with change history and the efficiently and traceable distribution/communication of new or changed content. Depending on organization culture also testing and examination tools for traceable learning must be integrated [17].
- The handling of collaborators' ideas, their discussion contributions and problem reporting must be implemented in accordance to the established systematic and structured process in accordance to ISO 9001 requirements. Their effectiveness must be evaluated.
- Open interfaces are needed to promote appropriate connectivity to other systems in order to support process integration and to reduce complexity [17]. As part of the controlling process all measurement data are communicated, evaluated by responsible departments

and when necessary changed and optimized by using the organizational learning system [1, 3].

- The web-based accessibility of the organizational knowledge system supports mobile working and hour's independent learning, teleworking and sustains the integration of absent collaborators [1, 18].

Introduction and Use

To promote the acceptance of the system the collaborators are trained on handling the system. They acquire necessary media competence [7, 12]. After, additionally questions are answered by means of the discussion forum, the service help desk and personal partners, e.g. the responsible for the regulations.

The constructivist organizational learning system enables every collaborator to introduce his/her suggestions, ideas or questions in a context-sensitive way by referencing directly to the related parts of the regulations. These questions and ideas are visible to all authorized collaborators. They can discuss the contributions and introduce their opinions on advantages and disadvantages. The answers to the questions are also visible to all authorized collaborators. Thus ambiguous formulations of the regulations are discussed and eliminated. The regulations represent the organizational knowledge base. It is the basis for the continual collaborative organizational learning and the continual performance improvement of the administration. New knowledge is build, distributed and shared among all interested collaborators.

The collaborators have sometimes difficult to distinguish between problem and optimization, or they do not know to which content they can relate their suggestion or question. Thus we have integrated the organizational learning system with the existing workflow driven problem reporting system (help desk system).

Clearly structured processes for the introduction of new collaborators, the improvement of the regulations and for the management of questions, optimizations and problems are established, documented, implemented and optimized.

Project Experience and Results

This organizational learning based regulation management concept has been implemented successfully in different medium-size public administrations. Most of their collaborators own good media competences and use frequently e-tools. The used organizational learning system should be still extended to fulfill all presented requirements (see IV C).

To summarize, the concept was useful and appreciated by all organizations to promote in common practice-oriented regulations and workplace integrated and need-oriented learning to improve the performance of the public administrations continually and to fulfill citizens' requirements and legal/regulatory compliance.

Achieving the Project Objectives

The elaboration of regulations, which are best adopted to the specific needs of each public administration, structured in accordance to ISO 9001 [8] and common principles of standards for management systems [10], prepared accordingly constructivist didactical principles and published on an organizational learning system (see section "Learning System Requirements") within a confident based open corporate culture leads to following case study results. They were collected by measuring the system accesses and user contributions and by interviewing managers and collaborators. The established objectives (see section "Purpose of the Article") were fulfilled:

- Need-oriented, workplace and process integrated access to the regulations for learning: the regulations were accessed on average two times monthly per collaborator.
- Organizational performance improvement: we received five times more suggestions and ideas for the improvement of the public administrations. The organizations achieved their planned objectives on average more than 92 %.
- Employee involvement and knowledge sharing: the communicated ideas, problems and suggestions are discussed and read on average by a quarter of the collaborators. On average there are three annotations to each discussion contribution. Thus the advantages and disadvantages of the ideas are discussed and examined by the departments before their possible implementation. Consequently they are substantially more balanced and more checked for implementation.
- Practice-oriented regulations: unclear formulations or missing content are soon discussed, analyzed, easily changed and communicated in accordance to the established processes. Thus the regulations are optimal adapted optimally to the changing requirements of the public administration, as well as citizens' and legal requirements.
- Shorter initial training periods for new collaborators: new collaborators are quickly introduced to handle the organizational learning system at their first working day. Thereby they focus on the handling of the software and on the most important key information. Afterwards, they access the regulations need-oriented and work-integrated, when they have questions to fulfill their job. In that way

the lead time for new collaborators could be abbreviated around a quarter. In addition new collaborators identify themselves substantially earlier with the corporate culture, feel themselves soon more integrated and can execute their job faster well. Thus their work performance increase earlier and possible errors are reduced.

The manager of one of the public administrations is particularly enthusiastic for the sustainable promotion of the open, confident based corporate culture by the organizational learning system. Criticism and change readiness is ongoing sustained.

The collaborators and particularly the management appreciate the structured, effective, need-oriented, location and working hour's independent learning. Thus no unnecessary regulations are distributed. Nevertheless all collaborators can access exactly at appropriate time from desired location to necessary regulations and knowledge. The improved internal transparency and the discussion board promote organizational interrelationship, mutual comprehension and synergies. The knowledge sharing by the discussion forum is especially appreciated by collaborators, which work frequently in field service, or on flexible working-time models or by teleworking.

Standard based management systems promote by their clear structure and systematic the establishment, check, approval, distribution, retrieval, use and the continual improvement of citizen oriented regulations.

Based on these experiences in the different case studies the application of this collaborative performance improvement concept is recommended for medium and large sized public administrations with a confidence-based, open and innovative corporate culture. The collaborators should be sufficient experienced in IT competences.

Success Factors

Corporate culture, services, processes, procedures, law requirements, didactical principles and information technology must be integrated optimally in accordance to the administration's specific corporate objectives and to the needs and requirements of the collaborators. Thereby the system, all concepts and methods are only tools, which support collaborative performance improvement and organizational development so far as this is admitted by corporate culture. Thus we need an open, confident based, collaborative corporate culture with criticism and change readiness [1, 19].

The collaborators must be interested in new knowledge, able for self-driven learning, have personal employment, team ability and change willingness apart from necessary IT and media competences [1]. All managers must use constantly and actively the system and motivate their collaborators in following these principles. In this way they promote workintegrated learning and continual performance improvement of the public administrations in a collaborative way. Thus trainings and education should promote self driven learning skills, team ability for knowledge sharing and necessary media competences.

The regulations must be established and optimized bottom up by involving concerned collaborators and regarding all relevant aspects in accordance to corporate administrations' objectives, citizens' and legal requirements. In that way concerned collaborators support the project, develop practice oriented regulations with daily used terms and integrate most of the explicit organizational knowledge. Unnecessary regulations are eliminated and too complex regulations are optimized. A great challenge is the right depth of regulations: to promote efficient and effective learning there should be integrated as much as needed and as less as possible.

The concept extends the job of the responsible for the regulations. They need additionally didactical and mediapedagogical knowledge for preparing the content and necessary skills for supporting collaborative learning and knowledge management. Trainings and education in public management or knowledge management should consider more this interdisciplinary approach and teach basic knowledge in all areas.

Sufficient IT-infrastructure and IT-support are also very important for the project success. Only by using an organizational learning system, which meets as far as possible the stated requirements (section "Learning System Requirements") and by promoting workplace, need-oriented, operations integrated learning the continual performance improvement of the public administration is secured. In that way the sustainable organizational development in accordance to defined objectives is promoted. Thus e-learning systems or knowledge management platforms should be extended to collaborative organizational learning systems in accordance to the stated requirements (section "Learning System Requirements").

Costs and Benefits

This innovative interdisciplinary collaborative performance improvement concept requires additionally in comparison to the common practice for regulation management (the elaboration, approval, communication and improvement) and the common applied introduction of a standard-based comprehensive management system, which is best adapted to the organization, the restructuring of the regulations in accordance to didactical principles, the organizational learning system and the implementation of the regulations on it.

The restructuring required in the case studies a slightly higher effort (approximately 1–2 % of the total effort).

Opposite to the costs there are the large advantages through the need-oriented process integrated regulation access to improve the performance and reduce the costs of the public administration by collaborators' ideas, suggestions and discussion contributions. These advantages can be measured on one hand by the achieved projects' objectives (see section "Achieving the Project Objectives"). The impact of the sustainable achievement of the established corporate objectives must be weighted essentially stronger. In accordance to general system theory the different corporate objectives and the aligned strategies influence each other and all individual actions together determine the achievement of the corporate objectives. This is at the end the essential critical success factor. The effects must be evaluated in a longer term and could be objective of subsequent studies.

Outlook

Learning systems should be extended to organizational learning systems (see section "Learning System Requirements") for need-oriented, workplace integrated access to regulations to promote continual performance improvement of the public administrations.

By introducing an organizational learning system for regulation management and the continual performance improvement of public administrations all success factors should be considered (see section "Success Factors").

Trainings in new public management, standard based management systems, organization, e-learning, knowledge management, information or regulation management should consider this interdisciplinary, collaborative and learning based approach.

The standards for management systems should underline more and promote the importance of an open, confident based, fault-tolerant corporate and learning culture, knowledge management and workplace integrated learning.

Conclusion

The elaboration of regulations, which are best adopted to the specific needs of each public administration, structured in accordance to ISO 9001 [8] and common principles of standards for management systems [10], prepared accordingly constructivist didactical principles and published on the organizational learning system (see section "Learning System Requirements") within a confident based open corporate culture promotes practice-oriented regulations, workplace and process integrated, need-oriented learning and the continual, collaborative performance improvement of public administrations. In addition the collaborators share their knowledge and the initial training periods can be reduced significantly. This collaborative performance improvement concept promotes service and process improvement, citizens' orientation and legal compliance.

Acknowledgment The research leading to these results was partially funded by the Tyrolean business development agency through the Stiftungsassistenz QE—Lab.

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From Information Security Management to Enterprise Risk Management

Margareth Stoll

Abstract

Organizations are faced with increasing complexity, uncertainty and enhanced threats from a wide range of forces. Depending on how this situation is handled, it can become risk or opportunity to erode or enhance business value. In addition, organizations have to meet most different stakeholders', legal and regulatory risk management requirements. Thus, comprehensive enterprise risk management has become key challenge and core competence for organizations' sustainable success. Given the central role of information security management and the common goals with enterprise risk management, organizations need guidance how to extend information security management in order to fulfill enterprise risk management requirements. Yet, interdisciplinary security research at the organizational level is still missing. Accordingly, we propose a systemic framework, which guides organizations to promote enterprise risk management starting from information security management. The results of our case studies in different small and medium-sized organizations suggest that the framework was useful to promote enterprise risk management in an effective, efficient, cost-effective and sustainable way. New insights for practice and future research are offered.

Keywords

Information security management • Risk management • Enterprise risk management • Framework • ISO 27000 • ISO 31000 • COSO

Introduction

Starting Situation

Uncertainty and risks are growing due to increased dynamic, complex and interrelated economy and enhanced threats from a wide range of forces, such as financial instability, political movements and terrorism, societal requirements, extreme nature events due to climate change, product recalls over more levels of the supply chain, pandemics, technical failures, frauds, espionage, sabotage, cyber-attacks and others. In the last years there were different low-probability and high-impact events, Black Swan events [1], which are almost impossible to forecast (e.g., drought, earthquake, floods, cyber-attacks). Depending on how uncertainty is handled, it can become opportunity or threat [2]. Thus, organizations have to meet most different stakeholders' risk management requirements to promote trust and long-term organizations' success. More and more organizations are reducing their business risks by seeking assurance that their supplier and partners are properly managing their risks. In the last years the number of certificates for information security management accordingly ISO/IEC 27001, for example, was growing worldwide over 20 % per year and for food safety accordingly ISO 22000 more than 34 % [3]. Since more than 10 years regulatory and legal authorities require increased corporate responsibility [4] with a broad

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_2,

focus on most different risks [5] (e.g., Sarbanes-Oxley Act (SOX), SEC Rule 33-9089, the King Reports in South Africa, the EU company directives [6] and national laws [7]). The major ratings agencies have integrated enterprise risk management into their financial reviews and company ratings [8, 9].

Thus enterprise risk management—the generic, systemic approach to identify and manage all the risks facing an organization related to their strategic objectives—has become key challenge and opportunity for modern organizations. It is a key differentiator for competitive advantages and sustainable organizations' success (cf. [10–12]). Enterprise risk management is a new topic overall for nonfinancial companies [2]. It has become core topic in management accounting. Nevertheless, many organizations treat enterprise risk management as compliance exercises and hinder their performance and flexibility [13]. Effective and coherent managed uncertainty across the whole organization enhances risk information and awareness [8], decreases uncertainty (e.g. stock price volatility [9]), reduces expected costs of external capital [14], facilitates informed decisions [4] and resource allocation [8], promotes performance in business operations [8, 15], ensures accountability, transparency and governance [4] and improves strategic planning, reputation and organizations' value [8–10].

Purpose of the Article

Traditionally, organizations managed risks in "silos" [9, 16], such as finance, market, compliance, regulation, infrastructure security, product safety, quality, health and safety, reliability and capacity of the production or service, global supply chain and logistics, litigation, governance, information security, environmental impacts, human resources, intellectual property rights, innovation and others. But risks interrelate in a cybernetic way (e.g. necessary health data to reduce safety risks or economic information to reduce financial risks can be critical for data protection). Recently organizations adopt more comprehensive approaches and aggregate the results of the different risk assessments into an organization-wide risk profile [17]. The Committee of Sponsoring Organizations (COSO) of the Treadway Commission and the International Standard Organization by ISO 31000 issued generic frameworks for enterprise risk management. Apart from larger organizations in sectors with tradition in risk assessment (e.g., banking, assurance), enterprise risk management is still in the early stages of development and implementation [4, 18].

Given the central role of knowledge, information and supporting technologies, information security—the availability of all essential assets, confidentiality, data integrity and legal/regulatory compliance—is one of the most important challenges for today's organizations [19]. At the end of 2010 more than 15,600 organizations worldwide were implementing information security management and obtained certification accordingly ISO 27001 [3]. Several best practices (e.g., COBIT, ITIL) and national guidelines (e.g., NIST 800-53, German IT Security Guidelines) for information security management are widely used in practice. Despite the common goals of information security and enterprise risk management, they provide no guidance to promote enterprise risk management by information security management. Accordingly Ashby's Law of Requisite Variety [20] the given complexity and dynamic requires a systemic approach. Thus, organizations need a meta-model, which integrates the different parts to a whole. This offers great advantages to identify those areas where efforts return most value. Since some years there are calls for more interdisciplinary security research [21, 22] and for studies at the group and organizational level [21]. Despite these, we found no systemic framework for extending information security management to enterprise risk management.

Research Question and Approach

How can we extend information security management accordingly IEC/ISO 27001 to fulfill enterprise-specific stakeholders', business and legal/regulatory enterprise risk management requirements? We expect, that our systemic framework guides organizations to promote enterprise risk management by security management in an effective, efficient/cost-effective and sustainable way. The framework was implemented and tested in different small and medium-sized organizations. The case study results were collected by established process and system measurement methods and by interviewing managers and collaborators.

Structure of the Article

Firstly we review previous approaches, describe the requirements for enterprise risk management (section "Previous Research and Requirements for Enterprise Risk Management") and present the core requirements of information security management accordingly ISO/IEC 27001 (section "Core Requirements of Information Security Management Systems"). Our integrated framework for enterprise risk management based on information security management (section "Integrated Framework") and its implementation (section "Implementation") are presented. We report about the case study results in different small and medium-sized organizations (section "Project Experiences and Results") with the achievement of project objectives (section "Achieving the Project Objectives") and discuss obtained findings, limitations and implications for practice and research (section "Findings, Limitations and Implications"). We conclude by summarizing our experiences (section "Conclusion").

Previous Research and Requirements

Previous Research and Requirements for Enterprise Risk Management

For a long time, information security was seen as a technical job and an integral part of the IT department [23]. Corresponding frameworks start at the process level and go down through all technical levels accordingly an IT enterprise architecture approach (e.g., [24–26]). But there are huge potential threats and organizations need to invest security efforts effectively. Governance oriented frameworks integrate or align the security strategy to the organizational and IT strategy and deduce policies, standards and procedures for the tactical and operational level. Operational measurement data are reported back to middle and top management (e.g., [27–29]). Due to the great impact of human-caused incidents recently a lot of research regards people-oriented issues, such as awareness, policy compliance, trust and others (cf. [21, 22]). Several best practices (e.g., COBIT, ITIL) and national guidelines (e.g., NIST 800-53, German IT Security Guidelines) are widely used in practice.

COSO provides a strategic-aligned, generic framework, which requires to: align risk appetite and strategy, enhance risk response decisions, reduce operational surprises and losses, identify and manage multiple and cross company risks, seize opportunities and improve the deployment of capital [30]. ISO 31000 provides principles, a framework and a process for managing risks [11].

Based on research results, COSO and ISO 31000 the main success factors of enterprise risk management are to create value, be committed by board management, become integral part of all organizational processes and decision making, address explicitly uncertainty, be systematic, structured and timely, base on best available information, be tailored to the organizations' specific context, take into account human and cultural factors, be transparent and inclusive, respond to changes in a dynamic, iterative and responsive way and facilitate the continual improvement of the organization [8, 11, 18, 30]. Organizations typically concentrate on managing known risks, which prevent them from seeing new risks [31]. Thus, the continual communication and consulting with internal and external stakeholders and the ongoing monitoring and improvement are essential success factors [11, 18, 30]. Enterprise risk management requires an interdisciplinary risk management team with collaborators of all levels [4, 11, 18, 30]. Insider threats (such as theft, fraud, violation of intellectual property) have caused the majority of economic losses and they are still growing [32]. Tools, processes, methods, technology and risk culture must be optimally harmonized, aligned with corporate objectives and continually improved [11, 30–34].

Core Requirements of Information Security Management Systems

The ISO/IEC 27001 family for information security management requires following core principles [35]:

- The defined corporate security policy regards legal/regulatory requirements and is approved by the management.
- A risk assessment must be conducted to establish the risk treatment plan in order to reduce risks to acceptable levels of risk. For the identified remaining risks the business continuity plan must be developed, implemented, maintained, tested and updated regularly.
- The needed resources must be determined and provided. All collaborators must be competent to perform their tasks. They must be aware of their activities' security impact and how they can contribute to achieve established objectives.
- The effectiveness, adequacy and compliance of the management system must be continually improved using measurements, monitoring, audits, management reviews and by applying corrective and preventive actions in sense of a PDCA (plan, do, check, act) cycle.

The management system must be systematically documented, communicated, implemented and continually improved.

Integrated Framework

Based on previous research, the requirements of enterprise risk management and the presented core requirements of ISO/IEC 27001 (see section "Previous Research and Requirements") we developed an integrated framework in order to fulfill enterprise-specific stakeholders', business and legal/regulatory enterprise risk management requirements by extending information security management:

- The security policy is extended by risk management aspects to an integrated corporate policy (see top of Fig. 1). Thereby the requirements of all stakeholders, as well as legal and regulatory requirements are regarded. Appropriate corporate risk objectives and strategies are established.
- Risk assessments are conducted to establish the risk treatment plan in order to reduce risks to acceptable levels of risk. For the identified remaining risks, potential emergency situations and accidents business continuity and emergency plans accordingly adequate standards, such

Fig. 1 The integrated framework

as ISO 22320 and ISO 22301 are developed (see the text under the top of Fig. 1).

- For all business processes risk objectives are deduced from corporate objectives by regarding business, legal and regulatory requirements and contractual obligations, specific conditions, uncertainties, threats, infrastructures and supporting services or technologies. The processes are analyzed and optimized accordingly these objectives (see middle of Fig. 1: main business processes start from the first contact with the customers and their requirements and end with the delivery of the products/services and the satisfaction of the customers). Thereby the identified risk treatments, business continuity and emergency plans are suitably integrated into the operational processes. They are implemented, maintained, tested and updated regularly to ensure effectiveness. The process description establishes for all process steps the associated responsible and accountable function and relevant risk management requirements. Thus, clear and traceable roles and responsibilities are assigned.
- The resource management deduces specific competence objectives from corporate and process objectives for all organizational functions and partners of the supply chain. Appropriate trainings or other actions are taken to achieve and maintain these objectives. Their effectiveness is evaluated. In that way the collaborators' awareness for risk management is constantly identified and improved. The organization defines, plans and provides the necessary resources, tools and instruments to obtain and improve the established objectives (see bottom of Fig. 1).
- The effectiveness and adequacy of the established enterprise risk management and the achievement of the objectives are evaluated periodically by suitable methods for monitoring and measurement (see the circle in Fig. 1). It is improved continually in accordance to established processes in sense of a PDCA cycle.
- A main success factor for enterprise risk management is adequate risk awareness of all collaborators and partners. Risk management must become part of corporate culture (see right of Fig. 1).

Implementation

Policy, Objectives and Strategies

Starting from internal and external stakeholders' and legal/regulatory requirements, key drivers and trends, contractual obligations, the characteristics of the business, the organization with its values, beliefs, ethic, culture, capabilities, capital, people, structures, its environment (culture, politic, finance, economic, nature, market and competition), resources, assets/ technology and all other particulars and requirements we extend based on Quality Function Deployment [36] the information security policy to the comprehensive corporate policy including risk aspects. The policy is elaborated with all key decision makers, stakeholders' representatives, if possible, and depending on the corporate culture preferably with collaborators of all levels and functions in an interdisciplinary approach. Based on the balanced scorecard [37] we define the priorities for conflicting interests and deduce enterprise risk management objectives and strategies from corporate policy. Depending on the size of the organization, we restrict the scope of enterprise risk management and define necessary boundaries. By establishing the policy, objectives and strategies we consider especially uncertainty and societal, legal/regulatory risks and requirements for all markets. Thus the entire organization is focused on enterprise-specific stakeholders', business and legal/regulatory enterprise risk management objectives.

Risk Assessment, Risk Treatment and Business Continuity Plan

Risk assessments for all relevant risk categories are conducted to establish risk treatment plans in order to reduce risks to acceptable levels of risk. Based on the established corporate policy we define the required risk criteria and risk levels for all relevant different sources of risk. After we identify for the specific organization the potential threats and risks for achieving established objectives, the likelihood of events, the areas and impacts of this events, the controls currently implemented, estimate the levels of remaining risks regarding the implemented controls (required level * likelihood * impacts) and elaborate for the remaining higher risks adequate risk treatments. Thereby we apply a systemic approach and regard the risks' interrelations. The board management approves whether the risks are acceptable or further risk treatments are to propose. For the established risk treatments control objectives and controls are selected and approved. Based on scenario analysis we define low-probable and high-impact events, the black swans. For the black swans and the identified remaining risks integrated business continuity and emergency plans are developed accordingly ISO 22320 and ISO 22301.

Process Analysis and Process Improvement

The management process, all business processes including supporting processes, resources processes and optimization processes are analyzed bottom up by interviewing the concerned collaborators. Based on process reengineering [38] all processes are optimized to meet deduced strategic-aligned risk objectives, as well as process-specific enterprise risk management requirements and uncertainties. In that way enterprise risk management is coherently and effectively integrated into all processes. The established measures from the risk treatment and business continuity/emergency plans are suitably integrated into relevant operational processes. We integrate, for example, appropriate risk assessments in sales processes and suppliers' selection, adequate health and safety and environmental measures into information security controls, recurring maintenance programs and plans into technical and infrastructure services. In that way we regard enterprise risk management by the development or change of products/services, processes, procedures, regulations, organizational structure, infrastructures, sites, supply chain, logistics, markets and others. Thus risk treatments, continuity and emergency measures are implemented, maintained and updated regularly to ensure that they are effective. Their efficacy following incidents or critical accidents is periodically tested. Function profiles and required competences are deduced from the established roles to the different functions at the single process steps. In that way clear and traceable roles and responsibilities are assigned to all collaborators and partners.

Resource Management

The organization determines and provides and improves necessary resources, infrastructures, tools and instruments to meet the established enterprise risk management objectives. Appropriate infrastructures and resources promote ongoing adequate enterprise risk management for long-term organizations' success. Training and competence objectives are planed and implemented in accordance to the defined human resource processes. Thus the risk awareness and necessary competences of all collaborators and partners are promoted systematically and structured. The effectiveness is evaluated and when necessary, corrective actions are taken.

Corporate Culture

It is important to understand the culture of the organization, which influences profoundly employees' behavior [39]. We need an organizational culture that encourages employees to take ownership of risks and weight their potential rewards and hazards [32, 34]. Executives are responsible or have great impact for communicating the right risk culture [40]. They must lead by example and have to encourage/evaluate the collaborators and partners in following these principles. The extensive research for an adequate information security culture (cf. [21, 22]) provides guidance.

Continually Improvement

The achievement of deduced process's risk objectives is controlled by measurement methods and targets. When they are not achieved, corrective and eventually preventive actions are taken. Accordingly ISO/IEC 27001 all corrective actions, improvements or changes are elaborated by the interdisciplinary risk team. They are documented, approved, communicated, implemented and their effectiveness is evaluated. Collaborators' ideas, the results of periodically internal and external audits and stakeholders' feedbacks provide further improvements. Thus enterprise risk management is constantly evaluated and when necessary adjusted and improved.

System Documentation

In accordance to ISO/IEC 27001 the established corporate policy, objectives, strategies, processes, risk assessment and risk treatment plan, business continuity/emergency plan, function profiles, templates, checklists, policies, procedures and others are documented and communicated traceably to concerned collaborators/partners in order to become part of corporate culture (see section "Corporate Culture").

Project Experiences and Results

The integrated framework for enterprise risk management based on information security management (ISM) was implemented in different small and medium sized organizations (from 25 to 200 collaborators). To summarize, the integrated framework was easy to understand and adaptable for organizations' specific requirements. It was useful and appreciated by all organizations to meet in common enterprise-specific stakeholders', business and legal/regulatory enterprise risk management requirements.

Achieving the Project Objectives

The following case study results were collected by established process and system measurement methods and by interviewing managers and collaborators [38, 41]:

- Effectiveness: the fulfilment of established objectives is periodically controlled by defined measurement methods. When necessary, appropriate corrective/ preventive actions are implemented and their effectiveness controlled. The organizations met their planned objectives in average more than 92 %. The risk of non-payment, for example, could be reduced constantly over 6 years from 0.8 to 0.4 %.
- Efficiency and cost reduction: Integrating enterprise risk management into existing ISM uses synergies and reduces the efforts and costs about 10–20 %. The advantages are still higher during implementation, when additionally only the risk assessment is continually adopted and improved.
- Sustainable enterprise risk management: The strategicaligned, tight integration of enterprise risk management into all programs, projects and measures, the collaborators' involvement and the continual controlling of the objectives' accomplishment enhances sustainable risk management. In addition it is ongoing promoted by the ideas, optimizations and suggestions of the collaborators and further structured, systematic improvements (see section "Continually Improvement"). The awareness for risks and opportunities was ongoing maintained. Potential opportunities are recognized early and transformed to competitive advantages for sustainable organizations' success.

Findings, Limitations and Implications

The discussions in the cross-functional team during the extension of the ISM increased severely the risk awareness of the involved collaborators. Our case study results underline the importance of an adequate corporate culture and the essential role of executives (see section "Corporate Culture"). Due to the central role of legal/regulatory requirements and the impact of regional culture the implementation of the framework should be analyzed in other countries and multinational concerns. Further studies are needed also in large organizations.

All relevant legal and regulatory requirements are analyzed, implemented and maintained by the defined improvement processes. The reduced liability by increased legal/regulatory compliance and transparency, and the enhanced risk information for informed decisions were especially appreciated by board managers and CEOs. The collaborators appreciated the increased performance in business operations, for example by reduced outstanding payments.

The extension of ISM for enterprise risk management requires a suitable adapted security management. It must be ongoing and effectively implemented. Due to continual changing of the internal and external context an effectively, strong strategic-aligned implementation and the continual improvement are essential success factors.

Extending and concurrently simplifying processes, risk measurement/controlling (consistent with Gates et al. [8]) and overall maintaining ongoing risk awareness were great challenges for the organizations. Based on the results from the literature research and these challenges we call for more interdisciplinary, systemic information security and enterprise risk management research in most different directions. This integrated framework can be used as meta-model to structure the research streams and to promote interdisciplinary research at the organizational and inter-organizational level.

While Delarosa [42] describes the large efforts for enterprise risk management, our integrated, systemic framework uses synergies to introduce enterprise risk management efficiently, resources carefully and promptly. In addition, it can be implemented successively by integrating ongoing more risk disciplines. Thus, it provides an optimal enterprise risk management approach, overall for small and medium-sized organizations.

Sufficient and appropriate resources (e.g., personnel resources, infrastructures) and technology (e.g., production systems, technical equipment, IT systems) are important success factors to maintain ongoing the risk level accordingly established risk objectives in order to convert uncertainty into opportunities for long-term organizations' success.

This integrated, systemic comprehensive risk management framework requires from the information security manager profound risk assessment skills and basic understanding in the different other risk disciplines and corresponding legal/regulatory requirements. Teaching and trainings should regard these comprehensive competences' requirements.

Due to the excellent project experiences organizations should extend enhanced security management to enterprise risk management in accordance to this integrated framework in order to fulfill enterprise-specific stakeholders', business and legal/regulatory risk requirements for sustainable organizations' success.

Conclusion

Due to increased complexity, uncertainty and threats from a wide range of sources and enhanced stakeholders' and legal/ regulatory requirements enterprise risk management has become key challenge and core competence for organizations' sustainable success. Based on our case studies' results the systemic framework guides organizations to enhance enterprise risk management starting from information security management in an effective, efficient, cost-effective and sustainable way. Thus, it offers great opportunities, overall for small and medium-sized organizations, operating in innovative, volatile markets with high strategic, financial, operational and technical risks. We call for more interdisciplinary information security and risk management research in most different directions and at all organizational and interorganizational levels.

Acknowledgment The research leading to these results was partially funded by the Tyrolean business development agency through the Stiftungsassistenz QE—Lab.

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Information System Engineering Promotes Enterprise Risk Management

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Abstract

Organizations are faced with increasing complexity, uncertainty and enhanced threats from a wide range of forces. Depending on how this situation is handled, it can become risk or opportunity to erode or enhance business value. In addition, organizations have to meet most different stakeholders', legal and regulatory risk management requirements. Thus, comprehensive enterprise risk management has become key challenge and core competence for organizations' sustainable success. Despite there were studied several approaches to systematically secure information systems against information security breaches, we found no approach, which guides organizations to promote enterprise risk management by system engineering. Interdisciplinary information security research at the organizational level is still missing. Accordingly, we propose a systemic approach for system engineering requirement analysis in order to promote enterprise risk management. The results of our case studies suggest that the approach was useful to promote enterprise risk management in an effective and sustainable way. Legal/regulatory compliance and risk awareness were enhanced. New insights for practice and future research are offered.

Keywords

System development • Requirement engineering • Enterprise risk management • ISO 31000 • COSO

Introduction

Starting Situation

Uncertainty and risks are growing due to increased dynamic, complex and interrelated economy and enhanced threats from a wide range of forces, such as financial instability, political movements and terrorism, societal requirements, extreme nature events due to climate change, product recalls over more levels of the supply chain, pandemics, technical failures, frauds, espionage, sabotage, cyber-attacks and others. In the last years there were different low-probability and high-impact events, Black Swan events [1], which are almost impossible to forecast (e.g., drought, earthquake, floods). Depending on how uncertainty is handled, it can become opportunity or threat [2]. Thus, organizations have to meet most different stakeholders' risk management requirements to promote trust and long-term organizations' success. More and more organizations are reducing their business risks by seeking assurance that their supplier and partners are properly managing their risks. In the last years the number of certificates for information security management accordingly ISO/IEC 27001, for example, was growing worldwide over 20 % per year [3]. Since more than 10 years regulatory and legal authorities require increased corporate

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_3,

responsibility [4] with a broad focus on most different risks [5] (e.g., Sarbanes-Oxley Act (SOX), SEC Rule 33-9089, the EU company directives [6] and national laws [7]). The major ratings agencies have integrated enterprise risk management into their financial reviews and company ratings [8, 9].

Thus enterprise risk management—the generic, systemic approach to identify and manage all the risks facing an organization related to their strategic objectives—has become key challenge and opportunity for modern organizations. It is a key differentiator for competitive advantages and sustainable organizations' success (cf. [10–12]). Enterprise risk management is a new topic overall for nonfinancial companies [2]. It has become core topic in management accounting. Nevertheless, many organizations treat enterprise risk management as compliance exercises and hinder their performance and flexibility [13]. Effective and coherent managed uncertainty across the whole organization enhances risk information and awareness [8], decreases uncertainty (e.g. stock price volatility [9]), reduces expected costs of external capital [14], facilitates informed decisions [4] and resource allocation [8], promotes performance in business operations [8, 15], ensures accountability, transparency and governance [4] and improves strategic planning, reputation and organizations' value [8–10].

Purpose of the Article

Traditionally, organizations managed risks in "silos" [9, 16], such as finance, market, compliance, regulation, infrastructure security, product safety, quality, health and safety, reliability and capacity of the production or service, global supply chain and logistics, litigation, governance, information security, environmental impacts, human resources, intellectual property rights, innovation and others. But risks interrelate in a cybernetic way (e.g. necessary health data to reduce safety risks or economic information to reduce financial risks can be critical for data protection). Recently organizations adopt more comprehensive approaches and aggregate the results of the different risk assessments into an organization-wide risk profile [17]. The Committee of Sponsoring Organizations (COSO) of the Treadway Commission and the International Standard Organization by ISO 31000 issued generic frameworks for enterprise risk management.

Apart from larger organizations in sectors with tradition in risk assessment (e.g., banking, assurance), enterprise risk management is still in the early stages of development and implementation [4, 18].

Given the central role of information engineering in our IT-related economy, organizations need guidance to regard enterprise risk management by system engineering. This requires a systematic and comprehensive analysis of all the risks, which faces the organization related to their strategic objectives. There are different approaches to reduce the risks of the software development process itself (e.g. [19, 20]) or to regard information security risks by system engineering (cf. [21–23]). While information security presents a key risk and one of the most important challenges for today's organizations [24], it is not the only one. Accordingly Ashby's Law of Requisite Variety [25] the given complexity and dynamic requires an integrated, systemic approach to analyze system engineering requirements in order to promote enterprise risk management. Thus, organizations need a comprehensive approach, which integrates the different parts to a whole. This offers great advantages to identify those areas where efforts return most value. Since some years there are calls for more interdisciplinary security research [26, 27] and for studies at the group and organizational level [26]. Despite these, we found no systemic approach to promote enterprise risk management by system engineering.

More than 1.45 million organizations of different sizes and scopes are implementing worldwide a standard based management system, such as ISO 9001 for quality management or ISO/IEC 27001 for information security management [3]. All these management standards are based on common principles [28]. In accordance to the requirement for aligning system engineering with corporate strategy (cf. [29]) they provide an optimal basis to analyze the system engineering requirements.

Research Question and Approach

How can we analyze the system engineering requirements based on the common principles of standards for management systems in order to promote enterprise-specific stakeholders', business and legal/regulatory enterprise risk management requirements? We expect that our systemic approach guides organizations to promote enterprise risk management in order to enhance legal/regulatory compliance and risk awareness by system engineering in an effective and sustainable way. The approach was tested in different organizations. The case study results were collected by established process and system measurement methods and by interviewing managers and collaborators.

Structure of the Article

Firstly we review previous approaches, describe the requirements for enterprise risk management (section "Previous Research and Requirements for Enterprise Risk Management") and present the core requirements of standards for management systems (section "Core Requirements of

Standards for Management Systems”). Our systemic, comprehensive approach for analyzing system requirements in order to promote enterprise risk management (section “Approach”) is presented. We report about the case study results in different organizations (section “Project Experiences and Results”) with the achievement of project objectives (section “Achieving the Project Objectives”) and discuss the obtained findings, limitations and implications for practice and research (section “Findings, Limitations and Implications”). We conclude by summarizing our experiences (section “Conclusion”).

Previous Research and Requirements

Previous Research and Requirements for Enterprise Risk Management

Many approaches have been developed to face the risks in the software development process (e.g. [19, 20]). In the last years a lot of research was done to reduce information security risks by system engineering. Apart from early methodology missing generation, there were developed structural and object-oriented security methods, survivable approaches, information and responsibility modeling methods (cf. [21–23]). Due to the great impact of human-behavior recently there is a call for more user-involved and empirical evaluated security development research [26].

COSO provides a strategic-aligned, generic framework, which requires to: align risk appetite and strategy, enhance risk response decisions, reduce operational surprises and losses, identify and manage multiple and cross company risks, seize opportunities and improve the deployment of capital [30]. ISO 31000 provides principles, a framework and a process for managing risks [11].

Based on research results, COSO and ISO 31000 the main success factors of enterprise risk management are to create value, be committed by board management, become integral part of all organizational processes and decision making, address explicitly uncertainty, be systematic, structured and timely, base on best available information, be tailored to the organizations’ specific context, take into account human and cultural factors, be transparent and inclusive, respond to changes in a dynamic, iterative and responsive way and facilitate the continual improvement of the organization [8, 11, 18, 30]. Organizations typically concentrate on managing known risks, which prevent them from seeing new risks [31]. Thus, the continual communication and consulting with internal and external stakeholders and the ongoing monitoring and improvement are essential success factors [11, 18, 30]. Enterprise risk management requires an interdisciplinary risk management team with collaborators of all levels [4, 11, 18, 30]. Insider threats (such as theft, fraud,

Fig. 1 Core requirements of standards for management systems

violation of intellectual property) have caused the majority of economic losses and they are still growing [32]. Tools, processes, methods, technology and risk culture must be optimally harmonized, aligned with corporate objectives and continually improved [31–33].

Core Requirements of Standards for Management Systems

The ISO 9001 standard for quality management systems [34] and other standards for management systems are based on common core principles, which will be enhanced in the future [28]:

- The corporate policy, objectives and strategies must be established and communicated by regarding the requirements of interested parties/internal and external stakeholders (see top of Fig. 1).
- For all business processes (including management process, support processes, resource processes and optimization processes) are deduced objectives from corporate objectives by regarding specific business, legal and regulatory requirements. The processes are analyzed and optimized accordingly these objectives (see middle of Fig. 1: main business processes start from the first contact with the customers and their requirements and end with the delivery of the products/services and the satisfaction of the customers).
- Necessary resources (human resources, technology, infrastructures, tools and instruments) must be determined, provided and maintained to meet the established objectives and to improve the effectiveness (see bottom of Fig. 1). All responsibilities and authorities must be clear assigned and communicated.

- The effectiveness, performance, suitability and adequacy of the whole management system must be measured and analyzed (see the circle in Fig. 1). It must be improved continually accordingly established processes in sense of a PDCA cycle (plan, do, check, act).

In addition to these core principles some risk oriented standards (e.g., ISO/IEC 27001) and accordingly ISO/DGuide 83 [28] in future all standards require a risk assessment to assure intended outcomes and to prevent undesired effects.

Approach

Based on previous research, the requirements of enterprise risk management and the presented core requirements of standards for management systems (see section "Previous Research and Requirements") we developed our systemic approach to analyze system engineering requirements in order to promote enterprise-specific stakeholders', business and legal/regulatory enterprise risk management.

Stakeholder Oriented Corporate Risk Objectives

For establishing the corporate risk organization policy, objectives and strategies we use the quality function deployment theory [35]. We work in an interdisciplinary team with all key decision makers, stakeholders' representatives, if possible, and depending on the corporate culture preferably with collaborators of all levels and functions approach. We define and prioritize all internal and external stakeholders (shareholders, customers/market, collaborators, suppliers/partners and society/environment), as well as relevant legal/regulatory requirements. Based on the experiences from intensive contact between stakeholders and collaborators and/or interviews, literature research, market research we identify the stakeholder's expectations and legal/regulatory requirements. Based on the balanced scorecard [36] we define the priorities for conflicting interests and deduce the enterprise risk management policy and objectives. Regarding key drivers and trends, contractual obligations, the characteristics of the business, the organization with its values, beliefs, ethic, culture, capabilities, capital, people, structures, its environment (culture, politic, finance, economic, nature, market and competition), resources, assets/technology and all other particulars and requirements we elaborate appropriate enterprise risk management strategies. Depending on the size of the organization, we restrict the scope of enterprise risk management and define necessary boundaries. By establishing the policy, objectives and strategies we consider especially uncertainty and societal, legal/regulatory risks and requirements for all markets. Thus the entire organization is focused on enterprise-specific stakeholders', business and legal/regulatory enterprise risk management objectives.

Risk Assessment, Risk Treatment and Business Continuity Plan

Risk assessments for all relevant risk categories are conducted to establish risk treatment plans in order to reduce risks to acceptable levels of risk. Based on the established corporate policy we define the required risk criteria and risk levels for all relevant different sources of risk. After we identify for the specific organization the potential threats and risks for achieving established objectives, the likelihood of events, the areas and impacts of this events, the controls currently implemented, estimate the levels of remaining risks regarding the implemented controls (required level * likelihood * impacts) and elaborate for the remaining higher risks adequate risk treatments. Thereby we apply a systemic approach and regard the risks' interrelations. The board management approves whether the risks are acceptable or further risk treatments are to propose. For the established risk treatments control objectives and controls are selected and approved. Based on scenario analysis we define low-probable and high-impact events, the black swans. For the black swans and the identified remaining risks integrated business continuity and emergency plans are developed accordingly ISO 22320 and ISO 22301.

Process Analysis and Process Improvement

The business processes (e.g., management process, all business processes including supporting processes, resources processes and optimization processes) are analyzed bottom up by interviewing the concerned collaborators. Based on process reengineering [37] all processes are optimized to meet deduced strategic-aligned risk objectives, as well as process-specific enterprise risk management requirements coherently and effectively integrated into all processes. The established measures from the risk treatment and business continuity/emergency plans are suitably integrated into relevant operational processes. We integrate, for example, appropriate risk assessments in the sales process (e.g., liquidity check of potential customers, information security requirement analysis for ICT services) and suppliers' selection (e.g., environmental impact analysis for hazardous chemical products, energy efficiency of IT-infrastructures or production systems). In the same way, for example, recurring maintenance programs for technical and infrastructure services are promoted to promote adequate production

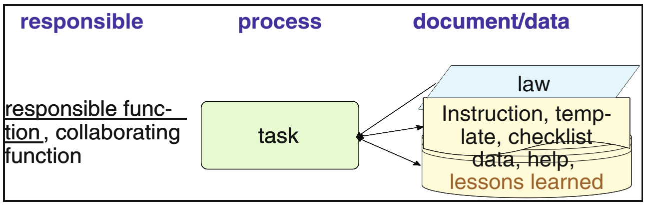

Fig. 2 Applied process documentation method

reliability. In an organization, which trades hazardous products, the maximal stock or transportation quantities are controlled accordingly environmental and health and safety laws. A structured, systematic comprehensive risk assessment becomes part of the IT-supported project management process. All documents and reports, for example contracts, are checked for legal and regulatory compliance. The process improvements are discussed in the interdisciplinary risk management team. The specialized, implicit knowledge of the experts is externalized and becomes part of the IT-system [38]. In that way we integrate enterprise risk management in all IT-supported business processes and promote organizational learning and knowledge exchange.

Analyzing the process steps we recognize these, in which experiences and special legal or regulation interpretations (lessons learned) are developed or new unknown risks maybe recognized (e.g., project evaluation). Based on the experiences by application in the work everyday life or if special, not clearly regulated, cases appear the risk prevention knowledge is extended or adjusted accordingly the continual improvement (see section "Resource Management"). In that way knowledge exchange and knowledge generation are promoted. The knowledge base and processes are changed in a systematic and flexible way [39]. In the same way knowledge, which is no more needed, is removed in time. Thus enterprise risk management, strategic-aligned process improvement, process modeling, process standardization, transparency and system engineering are optimally integrated to convert uncertainty into opportunities in order to enhance business value.

For the process documentation we use a simple form of flow charts, which is modeled by graphic support tools (Fig. 2). By process modeling for all process steps the responsible functions, as well as documents, information, tools, IT—applications and relevant legal and/or regulatory requirements are defined. This offers an optimal basis to analyze all information security requirements regarding confidentiality, availability and integrity, such as adequate access and signature rights, archiving procedures and others.

Based on the process model an user-oriented, context sensitive interface to the relevant legal and/or regulatory requirements for each process step can be integrated directly into the workflow. In another case the risk knowledge is exchanged by notes in the auxiliary system.

Function profiles and required competences are deduced from the established roles to the different functions at the single process steps. In that way clear and traceable roles and responsibilities are assigned to all collaborators and partners.

Resource Management

Due to standard requirements, the organization must determine, provide and improve necessary resources, infrastructures, tools and instruments to meet the established enterprise risk management objectives and to continually improve the organization. Appropriate infrastructures and resources promote ongoing adequate enterprise risk management for long-term organizations' success.

Training and competence objectives are planed and implemented in accordance to the defined human resource processes. Their effectiveness must be evaluated. Thus the risk awareness and necessary competences of all collaborators and partners are promoted systematically and structured. The effectiveness is evaluated and when necessary, corrective actions are taken. The comprehensive, interdisciplinary risk management approach requires communication skills, self and social competencies, interest in new knowledge, change and learning willingness, team ability, openness and tolerance, as well as process- and strategic-thinking.

Continually Improvement

Due to standard requirements the accomplishment of business processes' objectives must be continually controlled by measurement methods and targets. Thus the achievement of deduced process's risk objectives is promoted by adequate IT-supported enterprise risk controlling. In that way governance and transparency risks are reduced. When objectives are not achieved, corrective and eventually preventive actions must be taken. All corrective actions, improvements or changes are elaborated by the interdisciplinary risk management team. The necessary changes in the process model are documented, approved and implemented. Their effectiveness must be evaluated. Thus the changing organizational knowledge is documented, distributed and enhances new individual learning. New knowledge will be generated again and the knowledge and learning spiral is constantly pushed to extend the organizational knowledge base [39]. Collaborators' ideas, the results of periodically internal and external audits, stakeholders' feedbacks, the continually consulting with external stakeholders and the results of the periodically efficiency tests of the established continuity and emergency measures following incidents or critical accidents provide further improvements. In that way the

IT-supported enterprise risk management is constantly evaluated and when necessary adjusted and improved in a systematic, transparent and coherent way. The continual organizational development is promoted in accordance to enterprise-specific stakeholders', business and legal/regulatory requirements for long-term organizations' success.

IT Implementation

The established risk management integrated standard based management system defines the functional engineering requirements. It can be best integrated with all types of common system or software development methods, as Siponen [21] requires.

Project Experiences and Results

The systemic approach to promote enterprise risk management by system engineering was implemented successfully in different small and medium sized organizations (from 25 to 200 collaborators). To summarize, the integrated, systemic approach was useful and appreciated by all organizations in order to promote enterprise-specific stakeholders', business and legal/regulatory enterprise risk management.

Achieving the Project Objectives

The following case study results were collected by established process and system measurement methods and interviewing managers and collaborators:

- Legal/regulatory compliance: Due to the accurate analysis of relevant legal and regulatory requirements and their IT-supported, process-integrated implementation compliance was enhanced. All changes are analyzed and implemented systematically and structured in accordance to the established improvement processes. The reduced liability by increased legal/regulatory compliance and transparency were especially appreciated by board managers and CEOs.
- Risk awareness: The discussions in the cross-functional, interdisciplinary risk management team during the requirement engineering increased severely the risk awareness of involved collaborators. The awareness for risks and opportunities was ongoing maintained due to the tight integration of risk management into IT-supported processes and the continual improvement (see sustainability).
- Effectiveness: the fulfilment of the established risk objectives is periodically controlled by defined measurement methods. When necessary, appropriate corrective or preventive actions are implemented and their effectiveness is controlled. The organizations achieved their planned objectives in average more than 92 %. The risk of nonpayment, for example, was improved in an organization over 6 years from 0.8 % to 0.4 %. An optimal IT support promotes an efficient measurement. Many collaborators and especially executives appreciated the clear defined objectives and their continual measurement as helpful governance instrument.
- Sustainable enterprise risk management: The strategic aligned, tight integration of enterprise risk management into all programs, projects and measures, the collaborators' involvement and the continual controlling of the objectives' achievement promotes sustainable enterprise risk management. In addition it is ongoing promoted by the ideas, optimizations and suggestions of the collaborators and the further structured, systematic improvements. Potential opportunities are recognized early and transformed to competitive advantages for sustainable organization success.

Findings, Limitations and Implications

The use of standard based management systems as basis for the engineering requirement analysis requires a suitable adapted system for the specific organizations' needs. This is impossible buying external sample manuals. Due to the continual changing internal and external context, ongoing systematic, strategic-aligned improvement is essential. Implementing risk awareness and process thinking, harmonizing and simplifying processes, and risk controlling were great challenges and should be further investigated.

The involvement of concerned collaborators in cross-functional teams for analyzing the system engineering requirements promotes organizational learning (knowledge exchange and knowledge generation), process thinking and the user acceptance of the system. They appreciated the system as helpful tool and instrument to manage their job efficiently. In addition, the system is optimally adapted to enhance the ongoing accomplishment of the enterprise-specific stakeholders', business and legal/regulatory requirements for long-term organizations' success. Due to these project experiences, we call for a stronger use of organization-specific adopted standard based management systems as basis for requirement engineering.

Board managers and CEOs appreciated especially enhanced risk information for informed decisions. The collaborators valued the increased performance in business operations, for example by reduced outstanding payments.

Risk measurement/controlling (consistent with Gates et al. [8]) was a great challenge for the organizations. Based on the results from the literature research and our study results, we call for more interdisciplinary, systemic research on requirement engineering.

Our case study results underline the importance of an adequate corporate culture with team ability and change/learning willingness. Due to the central role of legal/regulatory requirements and the impact of regional culture the implementation of the framework should be analyzed in other countries and multinational concerns.

Sufficient, appropriate resources (e.g., personnel resources, infrastructures) and technology (e.g., IT-systems, engineering/development tools, IT-architecture, risk management systems) in accordance to corporate objectives are important success factors. Only appropriate resources support the ongoing conversion of uncertainty into opportunities for longterm organizations' success.

Conclusion

Growing complexity and uncertainty increased threats from most different sources and enhanced stakeholders' and legal/regulatory requirements for enterprise risk management. Thus enterprise risk management has become key challenge and core competence for organizations' sustainable success. Due to our case studies results the systemic approach to analyze systems' requirements based on best implemented standards for management system promotes organization specific stakeholders', business and legal/regulatory enterprise risk management in an effective and sustainable way. It offers great opportunities for organizations, operating in innovative, volatile markets with high strategic, financial, operational and technical risks. We call for stronger interdisciplinary system engineering research and the use of organization-specific adopted standard based management systems as basis for requirement engineering.

Acknowledgment The research leading to these results was partially funded by the Tyrolean business development agency through the Stiftungsassistenz QE – Lab.

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Simulation Study on the Performance of Reactive and Position-Based Routing Protocols in MANET

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Abstract

Recently, Mobile Ad Hoc NETwork (MANET) has drawn the attention of the research community particularly in routing protocols, such as the proactive, reactive and position-based routing. Invariably, the primary objective of routing protocols is transmitting the data packets from the source to the destination node. Therefore, these protocols can be distinguished based on the processes of searching, maintaining and recovering the routing path. A potential problem in MANET is identifying the best routing protocol. In this paper, we present performance evaluation study of reactive; Ad Hoc On-Demand Distance Vector (AODV) and position-based; Location-Aided Routing (LAR1). The performance evaluation study performed using QualNet v5.1 simulator. Additionally, the performance of those routing protocols investigated based on the throughput, delay, average jitter and energy consumption metrics varying the number of nodes. This results showed that the AODV has a better performance than LAR1 in terms of average jitter and throughput. While LAR1 performed better than AODV in terms of average end-to-end delay and energy consumption.

Keywords

MANET • Reactive routing protocol • Position-based routing protocol • AODV • LAR1

Introduction

The growing needs of wireless network and communication and their impact in all sorts of people lives have potentially drawn the attention of the research communities. There are two types of wireless network architectures; infrastructure and the infrastructurless wireless networks or MANET. The former has a permanent access point while the node of the mobile travels during the time of transmission. However, the node might go out of the range of access point and gets connected with any other available access points [1].

In MANET, the mobile nodes can move anywhere while communicating. In addition, all the nodes in functioning as routers. The nodes of the MANET dynamically create routes between themselves to form their own network [1].

This paper focuses on the MANET, in MANET, the process of routing is particularly vital as it involves in the transmission of information from one device to another. The routing in MANETs is multi-hop due to the range limitations of wireless radios [2]. The routing in MANETs has become a significant topic of research [3] is due to the problems on identifying and maintaining a route between the source-destination pair in a communication session [4].

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_4,

Many protocols proposed to address the MANET problems; nodes mobility, high power consumption, low bandwidth, and high inaccuracy rates. The distinctions of these protocols are on mechanism employed for updating of routing information; the two main categories of the mechanisms are topology-based routing protocols and position-based routing protocols. The topology-based routing protocols bifurcated into proactive and reactive routing protocols. However, the relative functionalities of all the proposed protocols have not been totally comprehended. It is hard to find document support in the literature to most of these protocols. Most of the MANET routing protocols have not been scrutinized or assessed so far [4].

The remainder of this paper is organized as follows: section "Routing Protocols of MANET" depicts the mechanisms of MANET routing protocols particularly those that assessed in this paper. Section "Related Work" reviews some associated literatures and related work. Section "Simulation Setup" present the simulation setup and environment and section "Result and Discussion" illustrates the result and evaluations followed by the conclusion in section "Conclusion".

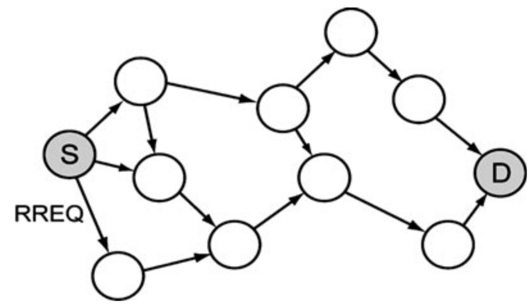

Fig. 1 Source node S initiates the path discovery process RREQ

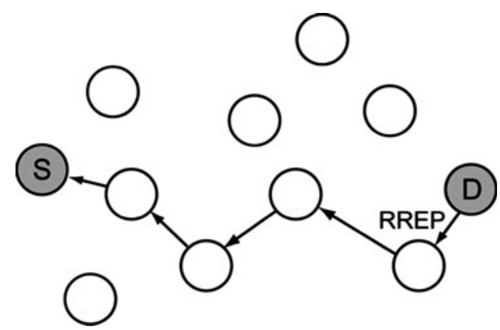

Fig. 2 Destination node D route reply RREP

Routing Protocols of MANET

Reactive Routing Protocols

Reactive routing protocols find out all routs as needed [5]. This reduces overhead created by proactive protocols. It uses flooding strategy to find a route. AODV protocol is a well-known reactive routing protocol in MANET [6]. When AODV attempts to send a packet to a target node with unknown an active route to it, the source node initiates a route discovery process [6]. In this process, the source node broadcasts the route request (RREQ) packet throughout MANET nodes, as shown in Fig. 1. If no intermediate node has a fresh enough route information to the destination node, the RREQ packet keeps its navigation until it reaches the destination node itself which in turn unicasts the route reply (RREP) packet towards the source node as shown in Fig. 2.

Position-Based Routing Protocols

Position-based routing can be done by means of positioning mechanisms such as Global Position System (GPS) [7] or radio position and GPS-less positioning systems [8]. The routing decision at each node base on the node's own position, the destination's position and the position of the routing node's neighbours. Typically, the packet forwarded to a neighbour that is closer to the destination than the routing node itself.

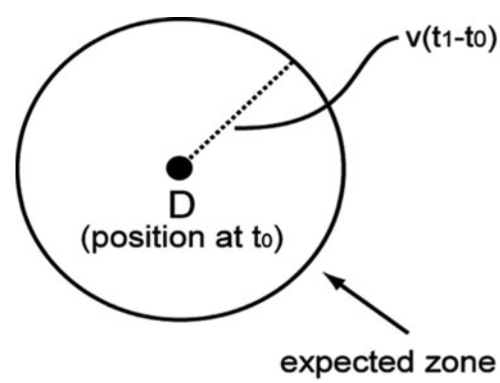

Fig. 3 LAR1 expected zone

LAR1 [9] using expected zone to detect the destination when a source node S wants to send a packet to the destination node D. LAR1 first tries to make a reasonable guess where D could be located. Assume node S knows that at time t_0 D's position was P and that the current time is t_1. In this case, node S is able to limit the expected zone of D from the viewpoint of node S by time t_1 as show in Fig. 3. For instance, if D move with a normal speed v, the source node S expects D to be in a circle around the old position P with a radius $v(t_1-t_0)$.

LAR1 uses also the concept of request zone [10]. Assume the sender node S knows the target node D's regular moving

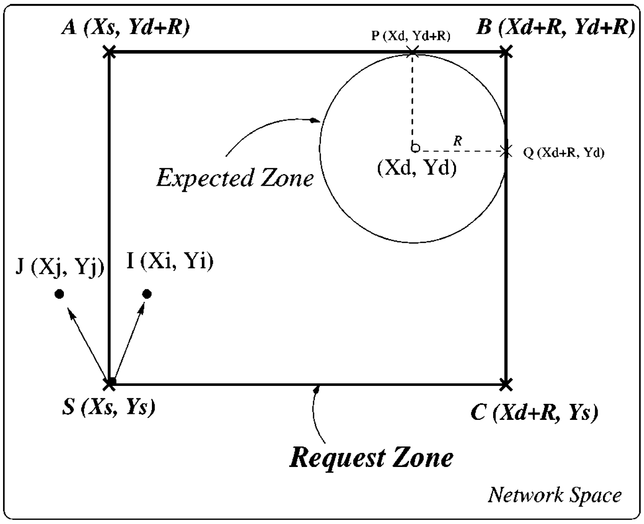

Fig. 4 LAR1 limited request zone and expected zone

and location (Xd, Yd) at time t_0. The request zone considered to be minimum rectangle that contains the current source location, and the expected zone. The sides of the rectangle are parallel to X and Y axes. The source node limited the request zone and creating the route request packet containing the four corners coordinates of request zone. Each intermediate node, receiving the request packet, checks whether it belongs to the rectangle; if it does not, it discards the packet such as node J does in Fig. 4. In Fig. 4, node I forwards the packet because it belongs to the rectangle. In the reply packet, node D attaches its accurate location and the current time stamp, which will be stored in the source's cache for future use.

Related Work

A performance analysis study for reactive routing protocols such as AODV and Dynamic Source Routing (DSR) is available in [11]. According to this study, the performance of AODV is better in the dense environment except packet loss. In [10], the authors carried out a performance comparative analysis for four MANET routing protocols; AODV, DSR, LAR1 and Zone Routing Protocol (ZRP). The results of their study indicate that the performance of DSR in vast networks is extremely poor and subtle, as the tests reveal that the DSR consumes much time resulting in extremely high delays and delivers less than 30 % of the packets in a network that contains 200 nodes. Despite its higher routing overhead, the performance of AODV was found to be better in all network sizes. Furthermore, the LAR1 is superior to the AODV up to 200 nodes towards delivery ratio and routing overhead.

Simulation Setup

Performance Metrics

1. Average end-to-end delay
   The average end-to-end delay is the amount of time taken by a packet to move from source to destination. In QualNet v5.1, Constant Bit Rate (CBR) average end-to-end delay is calculated as follow:

$$CBR\_Average\ end-to-end\,delay = \frac{Total\,end-to-end\,Delay}{Number\ of\,Packets\ \mathrm{Received}} \tag{1}$$

2. Average jitter
   Jitter is the variation in the time between packets arriving, caused by network congestion, timing drift, or route changes. In QualNet v5.1, CBR server average jitter is calculated by the following formula:

$$\text{average jitter} = \text{abs(jitter(1))} + \text{abs}\left(\text{(jitter(2))} + \ldots{} + \left(\text{abs}\ \frac{\text{jitter (N-2)}}{\text{(N-2)}}\right)\right) \tag{2}$$

3. Throughput
   Throughput is the ratio of the total amount of data that a receiver receives from a sender to a time it takes for a receiver to get the last packet [12]. In QualNet v5.1, throughput is calculated by the following formula:

$$Throughput = \frac{Total\,bytes\,received \times 8}{End\,Time\,[s] - Start\,Time\,[s]} \tag{3}$$

4. Energy Consumption
   The maximum number of bits that can be sent is defined by the total battery energy divided by the required energy per bit. The total energy consumption E required to send k bits is [13]:

$$\begin{aligned} \mathrm{E} &= \mathrm{P_{on}}.T_{on} + P_{sp}.T_{Sp} + P_{tr}.T_{tr} + P_{Idle}.T_{Idle} \\ &= (P_t + P_{Co}).T_{on} + P_{sp}.T_{sp} + P_{tr}.T_{tr} + P_{Idle}.T_{Idel} \end{aligned} \tag{4}$$

Simulation Parameters

We used QualNet version 5.1 simulator [13] to evaluate the performance of AODV and LAR1 routing protocols. The parameters setup is illustrated in Table 1.

Table 1 Parameters of effect of the number of nodes

Parameter	Value
Number of nodes	20, 60, 100, 140, 180
Simulation time	1,200s
Simulation area	800 m × 1,200 m
Routing protocols	AODV and LAR1
Mobility model	Random way point
Packet size	512 bytes
PHY	802.11b
No of CBR traffic	5
Traffic rate	100 Packets/s
Bandwidth	2 Mbps
Type of traffic	CBR
Speed	(1–4) m/s
Transmission range	250 m
Pause time	30 s

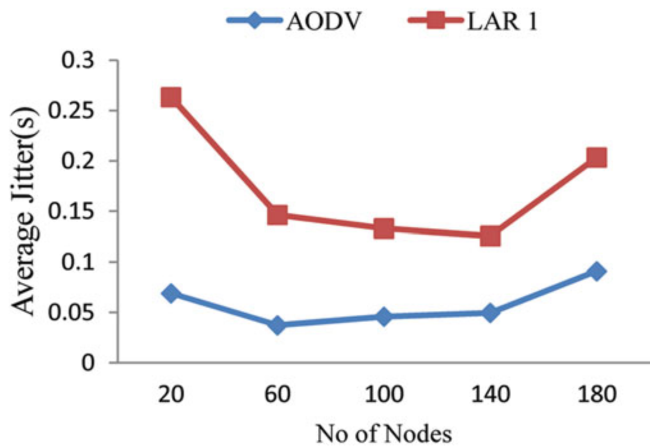

Fig. 5 Average jitter in AODV and LAR1 vs number of nodes

Result and Discussion

Average Jitter

As shown in Fig. 5. AODV has less average jitter than LAR1. This is because AODV has to establish the route between the source and destination node before sending any data packet. All the packets use the same route and hence the jitter between the packet and the next one will be a minimum. In contrast, in LAR1, each packet may use different route through its way toward the destination. This yield to increase the jitter between the packet and the next routing one.

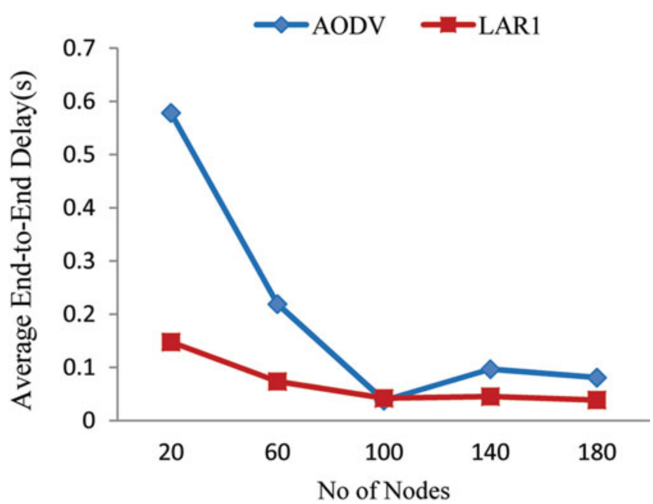

Fig. 6 Average end-to-end delay in AODV and LAR1 vs number of nodes

Average End-to-End Delay

Figure 6 shows that LAR1 has the least average end-to-end delay compare with AODV. LAR1 is position-based routing protocol. LAR1 does not need to calculate the routes like AODV, it is limited to the expect zone and send the data packets to the request zone. LAR1 is different from AODV since AODV send broadcast packets to all side.

Throughput

Figure 7 shows the influence of the number of nodes on network throughput on AODV and LAR1. The throughput values change according to the number of nodes for LAR1 and AODV. Figure 7 shows that AODV has better throughput than LAR1, as AODV use the efficient route to send the amount of packets to the destination. However, LAR1 has lower throughput than AODV due to data packets are not sent to the inefficient rout like AODV. This explains the LAR1 has low throughput compared with AODV.

Energy Consumption

The Energy consumption increases for two routing protocols with a starting scenario as shown in Fig. 8. On average, AODV has higher energy consumption than LAR1, AODV uses control packets during the route discovery and route maintenance. In addition, it has multi hop scheme rather than a single hop as in LAR1. Meaning AODV does require that all nodes process the RREQ packets as this would use much energy. In contrast, LAR1 send data packet to the except zone, and this requires less processing in the intermediate nodes.

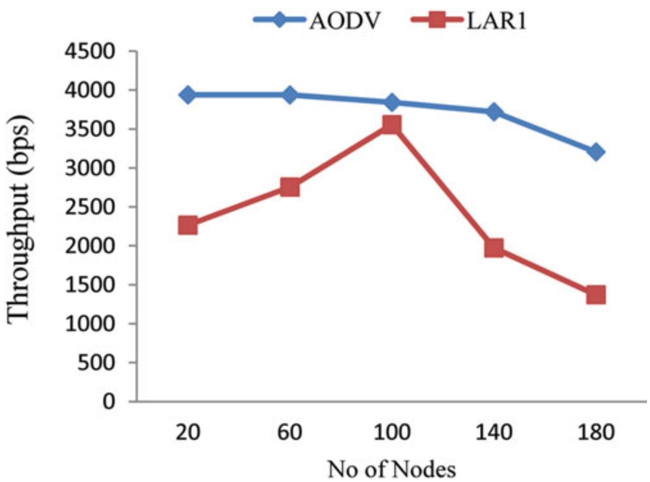

Fig. 7 Throughputs in AODV and LAR1 vs number of nodes

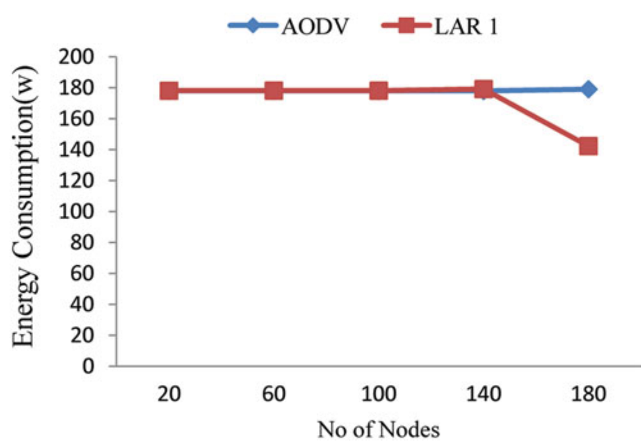

Fig. 8 Energy consumption in AODV and LAR1 vs number of nodes

Conclusion

In this paper, analysis and investigations carried out on two routing protocols AODV and LAR1 using QualNet V5.1. The AODV as the representative of reactive routing protocols and LAR1 as a position-based routing protocol. By changing the number of network's nodes number, the AODV had performed better than LAR1 in terms of average jitter and throughput while LAR1 performed better than AODV in terms of average end-to-end delay and energy consumption. As a future work, we have aimed to evaluate the effect of packet size on the performance of AODV and LAR1 using the same performance metrics.

Acknowledgment This research was supported in part by the Centre for Research and Instrumentation Management (CRIM), University Kebangsaan Malaysia. Grant: UKM-GGPM-ICT-035-2011.

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A New Approach for Buffer Queueing Evaluation Under Network Flows with Multi-scale Characteristics

Jeferson Wilian de Godoy Stênico and Lee Luan Ling

Abstract

In this paper, we propose a new analytical expression for estimating byte loss probability at a single server queue with multi-scale traffic arrivals. In order to make the estimation procedure numerically tractable without losing the accuracy, we assume and demonstrate that an exponential model is adequate for representing the relation between mean square and variance of Pareto distributed traffic processes under different time scale aggregation. Extensive experimental tests validate the efficiency and accuracy of the proposed loss probability estimation approach and its superior performance for applications in network connection with respect to some well-known approaches suggested in the literature.

Keywords

Network communications • Network flows • Network traffic • Buffer queueing

Introduction

Today communication networks must deal with a considerable number of different types of traffic, sharing common resources through statistical multiplexing. The efficient sharing of network resources depends on the statistical characteristics of traffic.

Historically the stochastic models widely used to characterize network traffic have been based on Poisson-like approaches, and more generally, Markovian modeling. Later, Leland et al [1] and other subsequent studies have demonstrated that traffic traces of modern high speed data networks exhibit fractal properties, such as self-similarity and long-range dependence (LRD) [2]. These new statistical traffic features, inadequately modeled by classical Poisson and Markov models, can strongly impact the performance of networks [3].

In contrast to the self-similar or monofractal behavior, some recent studies suggest that the measured TCP/IP and wireless traffic flows exhibit a more complex scaling behavior, which is consistent with multifractals [4, 5]. Multifractal based traffic modeling is more general than the monofractal based and provides a more accurate and detailed description of network traffic series in different time scales [6].

Even taking into account the influence of the long-range dependent characteristics [2], the expected queuing behavior in buffer still cannot be adequately modeled without considering the multifractal nature of traffic [7].

The loss probability and packet delay are key performance measures related to quality of service (QoS) in computer networks, such as TCP-IP and ATM. Several Studies have been conducted in order to characterize the average size of the queue and the distribution of the number of packets in the buffer [7–10].

In [7] a non-asymptotic multi-scale analysis on some queue models based on multifractal cascade concepts were performed. Interesting enough, the analysis is valid for any buffer size, i.e., the approach, named Multiscale Queuing, incorporates the distributions of traffic. In [8] some lower bounds of the loss probability for self-similar processes were derived.

In [9] the authors describe a statistical model for multi-scale traffic, deriving an equation for calculating the loss

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_5,

probability, whereas the input process traffic has lognormal distribution and that only the first two moments are sufficient to characterize the process of traffic. The derived analytical equation for the loss probability estimation is relatively complex and presents convergence when it is used numerically.

Moreover, in [10] the authors used an exponential approximation to model the second-order moment of the traffic process and derived an analytical expression for the loss probability estimation in a single server queue. It was assumed that the input traffic has a lognormal distribution. The derived analytical formula is computationally attractive overcoming the shortcoming of the analytical loss probability estimation equation obtained in [9] in terms of simplicity, accuracy and rapid convergence.

In this paper, our goal is to search for more accurate loss probability estimation methods without losing some similar advantages mentioned in [10], i.e., simplicity, accuracy and rapid convergence. We maintain the exponential approximation approach and demonstrate that it is adequate for representing the relation between mean square and variance of Pareto distributed traffic processes under different time scale aggregation. Via Simulation and tests over real network traffic traces, we validated the new approach for loss probability estimation in a single server link.

The paper is organized as follows. In section “Multi-scaling Traffic Processes and Their Characteristics”, we present the definition of the multi-scaling traffic processes, reviewing some their major concepts and analyzing the characteristics of the second-order statistical moments. In section “Loss Probability Estimation with Multi-scaling Input Processes”, we detail the derivation of the analytical expression for the loss probability estimation in a single server queue and our proposal for simplifying the analytical expression. In section “Experimental Evaluation of the Loss Probability Estimates”, we compare the proposed method to some well-known traffic models mentioned in the literature. Finally, in section “Conclusion” we present our conclusions.

Multi-scaling Traffic Processes and Their Characteristics

Definition 1. Let $X(t)$ be the traffic rate at t. Then $W(t) = \int_0^t X(t)dt$ will be the arriving load up to t. Denote by $V(t) = W(t + \Delta t) - W(t)$. The average traffic rate is $\lambda = lim_{\Delta t \to \infty} V(t)$.Given $T > 0$, the accumulative process $W(t)$ is said to be a multi-scaling process at time scale T if all of the following condition are satisfied:

- $W(t)$ has a stationary increment at time scale T, i.e., $V(t, T) = V(t)$;
- $V(t)$ has a Pareto distributed density function with parameter α and k: $f_{v(t)} = \frac{\alpha k^\alpha}{\nu^{\alpha+1}}$;
- $\mu = \lambda T$;
- There exist an integer $M > 0$, a set $A = \{\beta_i(T) : 0 < \beta_i(T) < 1, i \le M\}$, a set $\Phi = \{\phi_i(T) : 0 < \phi_i(T) < 1, i \le M, \sum_{i=1;M} \phi_i(T) = 1\}$, and a small constant $\varepsilon > 0$ such that for any $\tau \in \{\tau : T - \varepsilon < \tau < T + \varepsilon, \tau > 0\}$ such that

$$\sigma^2 \sim \sum_{i=1}^{M} \phi_i(T) \tau^{2\beta(T)}. \tag{1}$$

The expression (1) means there exists a probability measure for set A, and $\beta_i(T)$ occurs with probability $\phi_i(T)$. The continuous version of (1) is:

$$\sigma^2 \sim \int_{\infty}^{+\infty} f_{A(T)}(\beta) \tau^{2\beta} d\beta \tag{2}$$

where $f_{A(T)}$ denotes the probability density function of the scaling exponents $\beta(T)$. Notice that symbol “~” in (2) has the following interpretation: $x(p) \sim y(p)$ implies $lim_{u \to p}(x(u)/y(u)) = c$, where $0 < c < \infty$ is a constant.

Second-Order Moments of the Multi-scaling Processes

For simplicity, we assume that the scaling exponents $\beta(T)$ at time scale T of a traffic process follow a normal distribution $N(,\tilde{\alpha}, \tilde{\sigma}^2)$ with mean $\tilde{\alpha}$ and variance $\tilde{\sigma}^2$. Here we omit the subscript T for $\tilde{\alpha}$ and $\tilde{\sigma}^2$. Therefore, the variance of the distribution σ^2 of the traffic process at time scale T can be represented as:

$$\sigma^2 \sim \int_{\infty}^{\infty} \frac{1}{\sqrt{2\pi}\tilde{\sigma}} exp\left[-\frac{(\alpha - \tilde{\alpha})^2}{2\tilde{\sigma}^2}\right] T^{2\alpha} d\alpha \tag{3}$$

Let $z = T^{2\alpha}$, then $\alpha = ln(z)/(2ln(T))$ and $d\alpha/dz = dz/(2ln(T)z)$. Then Eq. (3) becomes

$$\sigma^2 \sim \int_{0}^{\infty} z \frac{1}{\sqrt{2\pi}(2ln(T)\tilde{\sigma})z} exp\left[-\frac{(ln(z) - (2ln(T)\tilde{\alpha}))^2}{2(2ln(T)\tilde{\sigma})^2}\right] dz \tag{4}$$

The right hand side of Eq. (4) shows that σ^2 simply has a log-normal distribution $L(\varpi, \theta)$ with parameters $\varpi = 2ln(T)\tilde{\alpha}$ and $\theta = 2ln(T)\ \tilde{\sigma})^2$. For the log-normal representation given by (4), a simple calculation can show that the mean μ and variance σ^2 of the distribution of the multi-scaling increment traffic process at time scale T are related to ϖ and θ as:

$$\mu = exp\left(\varpi + \theta^2/2\right) \tag{5}$$

and

$$\sigma^2 = exp\left(2\varpi + \theta^2\right)\left[exp\left(\theta^2\right) + 1\right] \tag{6}$$

Therefore,

$$\varpi = ln(\mu) - \frac{1}{2}ln\left(\frac{\sigma^2}{\mu^2} + 1\right) \tag{7}$$

and

$$\theta = \sqrt{ln\left(\frac{\sigma^2}{\mu^2 + 1}\right)} \tag{8}$$

Under the log-normal distribution of σ^2, it can be shown immediately that

$$\sigma^2 \sim exp\left[2ln(T)\widetilde{\alpha} + \; 2ln(T)\widetilde{\sigma})^2\right] = \; T^{2\widetilde{\alpha}}\,T^{2\widetilde{\sigma}}\,ln(T) \tag{9}$$

The Holder Exponent and Network Traffic

Definition 2 (**Pointwise Hölder exponent**): Let β be a real number and C be a constant, both strictly positive and $x_0 \in \mathbb{R}$. The function f:$\mathbb{R} \to \mathbb{R}$ is $C^\beta(x_0)$ if we can find a polynomial $P_n(x)$ of degree $n < \beta$ such as:

$$|f(x) - P_n(x - x_0)| < C|x - x_0|^\beta \tag{10}$$

The pointwise Hölder exponent β_p of function f at x_0 is defined as

$$\beta_p(x_0) = \sup\left\{\beta > 0 \middle| f \in C^\beta(x_0)\right\} \tag{11}$$

Notice that such a polynomial P_n can be found even the Taylor series expansion of f around x_0 does not exist.

As presented in Definition 2, the Hölder exponent of a time process at a particular time instance t_0 is related to the regularity level of the signal at that instance. In the context of network traffic traces, the exponent measures the degree of local variations of the traffic processes. More precisely, here we show how the traffic traces vary in terms of number of bytes or packages, on a range $[t_0; t_0 + \Delta t]$.

The Hölder exponent β can be also interpreted as a real number measure which locally controls the multi-scale behavior of the process. The networks traffic is said having

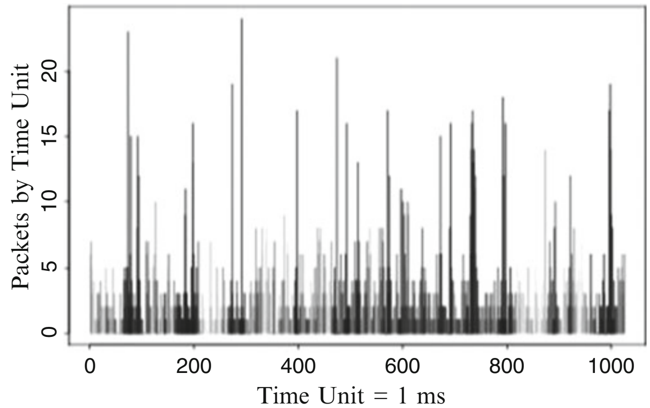


Fig. 1 Local regularity of dial 3 traffic trace represented in different gray levels: (dark) small Hölder exponents; (Clear) large Hölder exponents

local multi-scale behavior with Hölder exponent $\beta(t_0)$ at time if the traffic process rate behaves according to $(\Delta t)^{\beta(t_0)}$ when $\Delta t \to 0$. In terms of traffic behavior, when $\beta(t_0)$ has a smaller value near to zero, the traffic burst intensity becomes larger. On the other hand, when $\beta(t_0)$ approaches to one, a low intensity of traffic rate variation is generally observed.

For illustration propose, Fig. 1 shows in gray levels, the magnitudes of the Hölder exponent of traffic trace DIAL 3. This traffic trace is given by the number of packets at 1 ms time scale, collected from FDDI (Fiber Distributed Data Interface) ring at AT&T research laboratories [4]. Notice that the smaller the Hölder exponent, the more intense traffic burstiness and the darker gray level will become. In contrast, a clearer gray level is used to indicate regions with low burst occurrence, or higher Hölder exponent magnitudes.

Loss Probability Estimation with Multi-scaling Input Processes

Let $X(t)$ represent a multi-scaling traffic process with a Pareto distribution as follows:

$$f_{x(t)}(x) = \frac{\alpha k^\alpha}{x^{\alpha+1}} \text{ for } x > k \tag{12}$$

where $\mu = \frac{\alpha k}{\alpha - 1}$ and $\sigma^2 = \left(\frac{k}{\alpha-1}\right)^2\left(\frac{\alpha}{\alpha-2}\right)$ are mean and variance, respectively.

The distribution parameters α and k can be determined by the knowledge of the μ and σ^2 of the process X(t). In other words, the mean and variance values can be numerically estimated directly from given input network traffic flows. Therefore,

$$\alpha = \frac{\mu^2}{\sigma^2} \tag{13}$$

and

$$k = \mu - \frac{\sigma^2 \mu}{\mu^2} \tag{14}$$

or

$$\alpha = \frac{\mu^2}{\sigma^2} + 2 \tag{15}$$

and

$$k = \frac{\mu^3 + \sigma^2 \mu}{\mu^2 + 2\sigma^2} \tag{16}$$

In this section we derive an analytical expression for loss probability under a single server queue.

We assume that the single queue is stable with buffer capacity big enough to accommodate any eventual transient bursts. Then, the following balance equation can be established:

$$Q(t_0) + V(tt_0) = Q(t) + O(t - t_0) \tag{17}$$

where $Q(t)$ is the queue length at time t, $V(t–t_0) = W(t) – W(t - t_0)$ is the cumulative traffic load in the period $[t, t_0]$, and $O(t - t_0)$ denotes the traffic load leaving in (t_0, t). Here we assume

$$O(t) = C(t - I(t)) \tag{18}$$

where C is the constant service rate and $I(t)$ denotes the total server idle time of up to t. Let $V(0) = 0$ and $Q(0) = 0$. Therefore $Q(t)$ can be written as:

$$Q(t) = max(V(t) - O(t), 0) \tag{19}$$

Let $Y(t) = \text{V}\ (t) – Ct$ and $\Delta t = CI(t)$, Eq. (19) can be expressed:

$$Q(t) = max(Y(t) + \Delta t, 0) \tag{20}$$

Applying the law of total probability, the loss probability in queue can be calculated as:

$$\begin{aligned} P_{loss}(t) &= P(Q(t) > q) \\ &= P(Y(t) + \Delta(t) > q, Y(t) > q) \\ &\quad + P(Y(t) + \Delta(t) > q, Y(t) \le q) \\ &= P(Y(t) > q) \\ &\quad + P(Y(t) \le q < Y(t) + \Delta(t)) \end{aligned} \tag{21}$$

The first term $P(Y(t) > q)$ in (21) is called the absolute loss probability (P_{abs}) and the second term $P(Y(t) \le q \le \Delta(t))$ the opportunistic loss probability (P_{opp}). Assuming $Q(T)$ stationary, letting $\rho = 1 - \eta = 1 - \lambda / C$ and using the result derived by Benes [11], the second term (P_{opp}) can be written as:

$$\begin{aligned} P_{opp}(t) &= P(Y(t) \le q < Y(t) + \Delta(t)) \\ &= \rho \int_0^t f_{V(u)}(v)\big|_{v=Cu+q} du \end{aligned} \tag{22}$$

Also, the absolute loss probability (P_{abs}) can be written as an integral:

$$\begin{aligned} P_{abs}(t) &= P(Y(t) > q) = P(V(t) > Ct + q) \\ &= \int_{Ct+q}^{\infty} f_{V(t)}(v)\, dv \end{aligned} \tag{23}$$

Thus, the fully characterized queuing behavior of eventually any traffic type in term of information loss is given by:

$$P_{loss}(t) = \int_{Ct+q}^{\infty} f_{V(t)}(v)\, dPv + \rho \int_0^t f_{V(u)}(v)\big|_{v=Cu+q} du \tag{24}$$

The first term on the right side of Eq. (24) can be further detailedly expressed as:

$$P_{abs}(t) = \int_{Ct+q}^{\infty} f_{V(t)}(v)\, dv = \left(\frac{k}{x}\right)^{\alpha} \text{ for } x \ge k \tag{25}$$

Thus, the loss probability under the stationary state assumption is:

$$\begin{aligned} P_{steady}(t) &= \lim_{t\to\infty} P_{loss}(t) \\ &= \rho \sup_{t>0} \left\{ \int_0^t f_{\backslash V(u)}(v)\big|_{v=Cu+q} du \right\} \end{aligned} \tag{26}$$

or

$$P_{steady}(t) = \left(1 - \frac{\lambda}{C}\right) \int_0^{\infty} \frac{\alpha k^{\alpha}}{x^{\alpha+1}}\Big|_{x=Cu+q} du \tag{27}$$

Note that for multi-scaling traffic series the variables α and k can be calculated using Eqs. (13) and (14) or (15) and (16), respectively. Substituting the relations given by the Eqs. (13) and (14) into (27), the loss probability can be estimated by:

$$P_{steady}(t) = \left(1 - \frac{\lambda}{C}\right) \int_0^{\infty} \frac{\left(\frac{\mu^2}{\sigma^2}\right)\left(\mu - \frac{\sigma^2 \mu}{\mu^2}\right)^{\frac{\mu^2}{\sigma^2}}}{(Ct+q)^{\frac{\mu^2}{\sigma^2}} + 1} dt \tag{28}$$

Again, now substituting the relations given by the Eqs. (15) and (16) into (27), the loss probability can be estimated by:

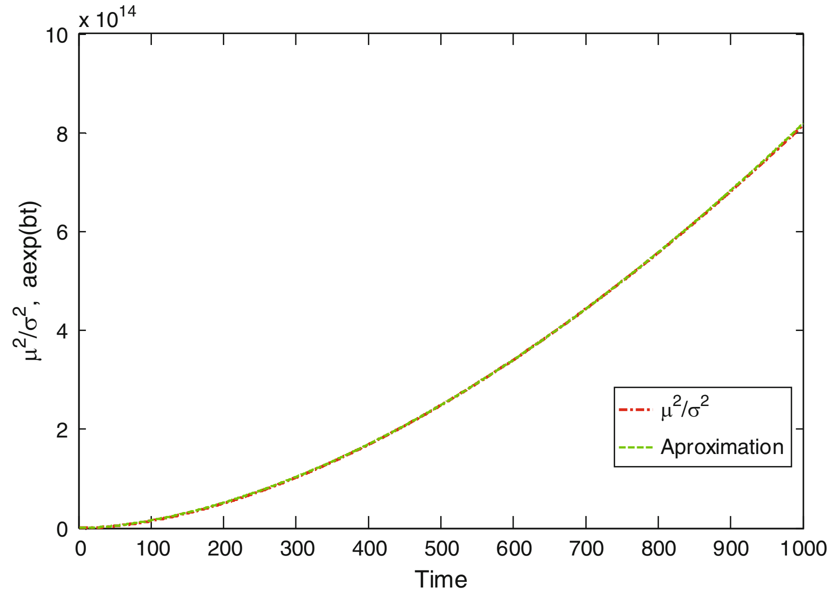


Fig. 2 Approximation

$$P_{steady}(t) = \left(1-\frac{\lambda}{C}\right)\int_0^\infty \frac{\left(\frac{\mu^2}{\sigma^2}+2\right)\left(\frac{\mu^3+\sigma^2\mu}{\mu^2+\sigma^2}\right)^{\frac{\mu^2}{\sigma^2}}+2}{(Ct+q)^{\frac{\mu^2}{\sigma^2}}+3}dt \quad (29)$$

where $\mu = \lambda T$ and $\alpha^2 = T^{2\tilde{\alpha}} T^{2\tilde{\alpha}\, ln(T)}$.

Our Approach for Loss Probability Estimation

In this work, we propose our approach for loss probability estimation. The major motivation of the proposed approach is to reduce the complexity of the numerical integration to be carried out in expressions (28) and (29). In other words, we propose the exponential approximation given in (30) to describe the relation between the square mean and the variance under time scale T in order to make the analytical expression for loss probability estimation simpler, more efficient without losing the accuracy of the estimates.

$$\frac{\mu^2}{\sigma^2} \cong aexp(bt) \quad (30)$$

where a and b are two parameters of the exponential functional model used for the desired fitting. In general, parameters a and b of the exponential fitting function is determined from applying the minimum mean square error approximation.

For illustration purpose, the green colored curve in Fig. 2 is the best exponential function fitting for real network traffic lbl_pkt_5 [12].

Under the exponential fitting function modeling given by (30), we have two expression for the steady state loss probability:

$$P_{steady}(t) = \left(1-\frac{\lambda}{C}\right)\int_0^\infty \frac{(aexp(bt))\Big((\lambda t)(aexp(bt))^{-1}(\lambda t)\Big)^{aexp(bt)}}{(Ct+q)^{aexp(bt)+1}}dt \quad (31)$$

or

$$P_{steady}(t) = \left(1-\frac{\lambda}{C}\right)\int_0^\infty \frac{(aexp(bt)+2)\left((\lambda t)\left(\frac{aexp(bt)+1}{aexp(bt)+2}\right)\right)^{aexp(bt)+2}}{(Ct+q)^{aexp(bt)+3}}dt \quad (32)$$

Figure 3 shows how the loss probability changes in terms of buffer size for two loss probability estimation equation given by (31) and (32) for traffic lbl_pkt_5. Clearly, two loss probability curves are very close.

Experimental Evaluation of the Loss Probability Estimates

In this section we show our simulation investigations by using one more real network traffic trace (lbl_pkt_5 and dec_pkt_1) to validate the proposed loss probability estimation approach. Accordingly, these traffic traces presents multi-scaling characteristics [13]. Table 1 summarizes the involved queuing system configurations (server capacity and buffer size) of the single server queue used in the simulation.

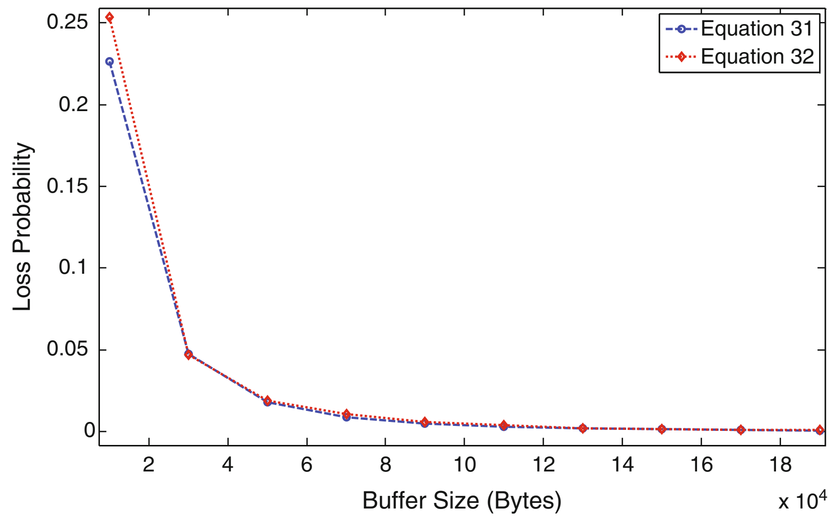


Fig. 3 Differences between Eqs. (31) and (32)

Table 1 Queuing system configuration

Traffic trace	Server capacity (bytes/s)	Buffer size (bytes)
lbl_pkt_5	1.2×10^4	3×10^4
dec_pkt_1	1.0×10^6	3×10^5

Table 2 Loss probability estimates

Traffic trace	lbl_pkt_5	dec_pkt_1
Simulation	8.14×10^{-4}	1.30×10^{-3}
Duffield	8.02×10^{-18}	5.61×10^{-19}
Lognormal	2.31×10^{-4}	4.39×10^{-5}
MSQ	2.05×10^{-6}	3.13×10^{-6}
CDTSQ	9.86×10^{-7}	1.45×10^{-6}
Proposed	4.92×10^{-4}	3.85×10^{-3}

Table 2 compares the loss probability estimates (in number of bytes) for these traffic traces feeding a single server queue scheme defined in Table 1, under the following methodologies, namely:

- Simulation: by simulations;
- MSQ: Multiscale Queue (MSQ) [7];
- CDTSQ: Critical Dyadic Time-Scale Queue (CDTSQ) [7];
- The Duffield: Duffield's method [8];
- Lognormal: the proposed exponential approach for variance with normal distribution and traffic having lognormal distribution [10];
- Proposed: our approach proposed in this paper.

Notice that the Duffield's method provides a lower bound of loss probability $P(Q > b)$ for self-similar processes. "Lognormal", "MSQ" and "CDTSQ" are three multi-scale analyses for network traffic with long-range-dependence [2]. Our proposed approach in this work can be viewed as an alternative and improved version for the Lognormal method proposed in.

Figures 4, 5, 6, and 7 compare how loss probability estimates vary in function of buffer size and different serve capacities, respectively, for the lbl_pkt_5 and dec_pkt_1 traces. Again, the proposed approach provides considerably better performances.

Conclusion

In this paper, we propose a new analytical expression for estimating the byte loss probability at a single server queue with multi-scale traffic arrivals. Initially, we address the definition concerning multi-scale processes, assuming the processes have Pareto distribution. Next, we focus our attention on the second order statistics for multi-scale processes, and more specifically, we assume that an exponential model is adequate for representing the relation between mean square and variance of the traffic process under different time scale aggregation. Then, we compare the performance of the proposed approach with some other relevant approaches (e.g., monofractal based methods, and multi-scale methods) using real traffic traces. The simulation results show that the proposed estimation of loss probability is simple and accurate.

Fig. 4 Loss probability versus server capacity for the traffic trace lbl_pkt_5

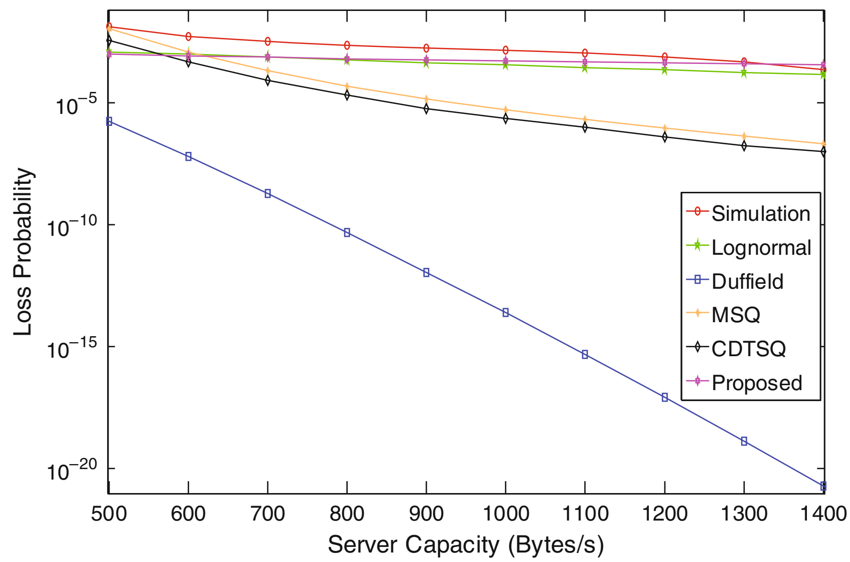


Fig. 5 Loss probability versus size of buffer for the traffic trace lbl_pkt_5

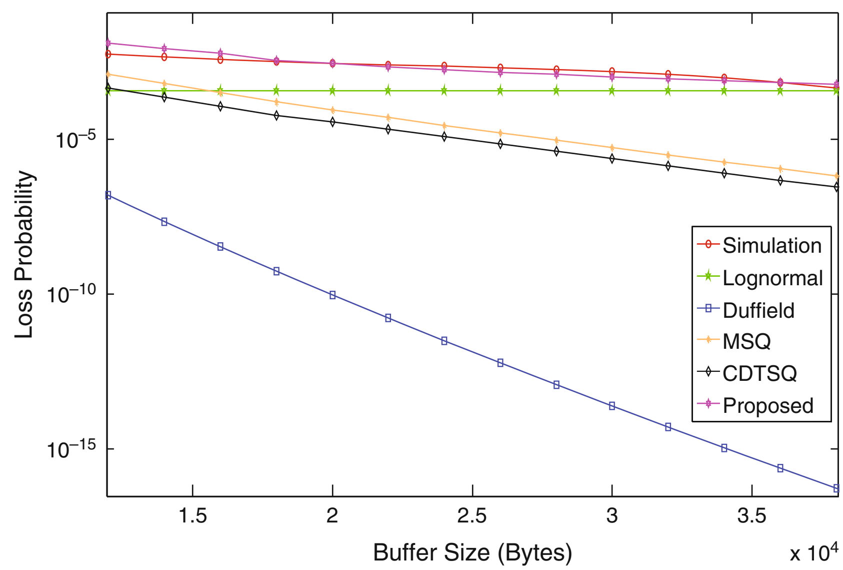
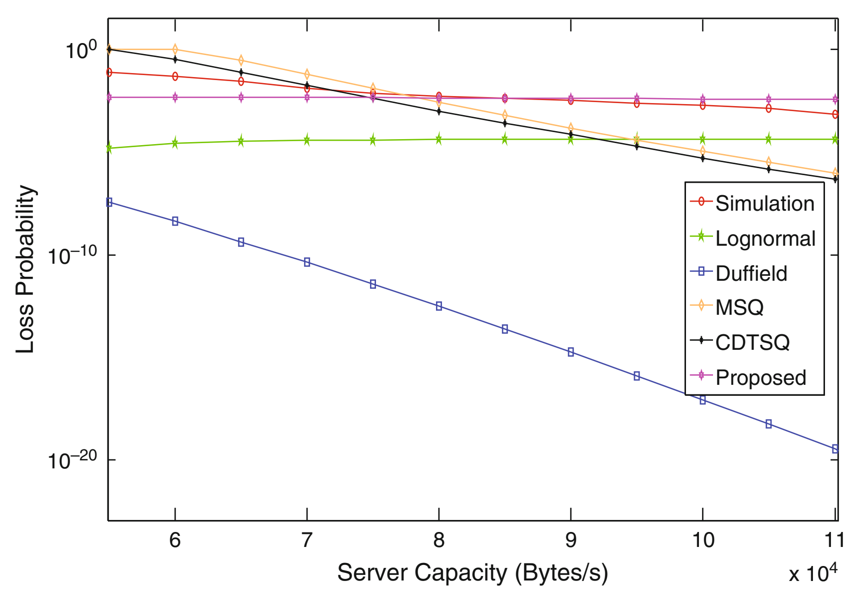


Fig. 6 Loss probability versus server capacity for the traffic trace dec_pkt_1



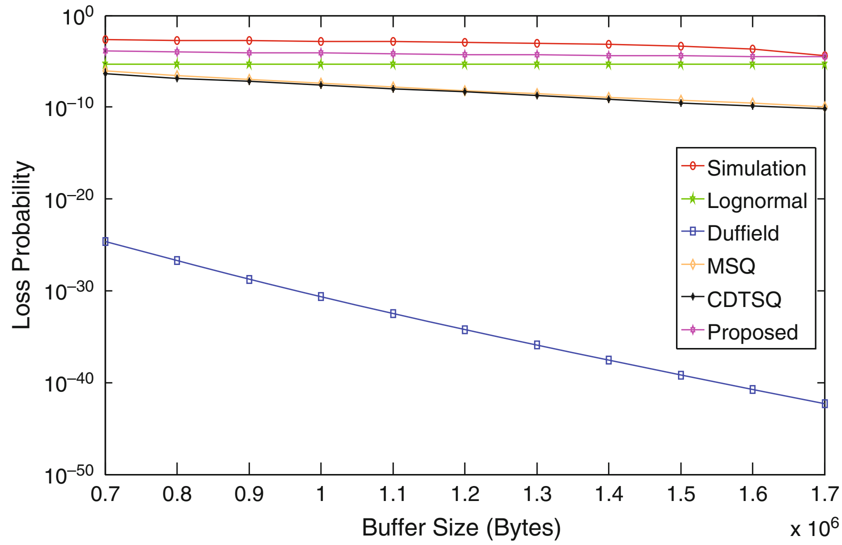


Fig. 7 Loss probability versus size of buffer for the traffic trace dec_pkt_1

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Polynomial Compensation of Odd Symmetric Nonlinear Actuators via Neural Network Modeling and Neural Network Describing Function

O. Kuljaca, K. Horvat, J. Gadewadikar, and B. Tare

Abstract

Paper deals with polynomial compensation of odd symmetric nonlinear actuators. Most actuators are nonlinear sporting odd symmetric nonlinearities such as deadzone and saturation. One way of dealing with such actuators is to try to compensate for nonlinearities by polynomial representation of inverse nonlinearity. Compensated actuators can improve behavior of the system, but then arises the problem of stability analysis because compensated nonlinearity is now complex nonlinearity not described in common literature. One way of dealing with such problem is to perform stability analysis via describing function method. Paper describes the method for compensating nonlinearities, recording describing function and performing stability analysis.

Keywords

Neural network • Polynomial compensation • Odd symmetrical nonlinearities • Compensated actuators

Introduction

In all control systems there are present actuators. Virtually all of them have nonlinearities. Depending on the control system these nonlinearities can be neglected or one has to deal with them in some way. Nonlinear control theory is reach with different methods of compensation or stability analysis of systems with nonlinear actuators [9, 11, 12].

Many actuators have odd nonlinearity followed by linear filter type element. Examples are many electrical motors, hydraulic cylinders and solenoid actuators. There are different methods for dealing with such systems (introduction of ditter signal, different anti wind-up schemes etc,). This paper deals with such nonlinearities compensated by polynomial representation of inverse actuator nonlinearity. Examples are given for compensated nonlinearities of type dead zone, saturation, deadzone with saturation and friction.

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Actuator with Odd Nonlinearity

Many actuators with odd nonlinearity can be represented by structure shown in Fig. 1.

Nonlinearity F(x) can be any odd type nonlinearity. Linear part of the system $G_L(p)$ can be any linear system as long as it is of low-pass filter type, i.e. it will damp higher frequencies.

Describing Function

Describing function is an equivalent gain of nonlinear element, defined by the harmonic linearization method of nonlinear static characteristic [1, 2, 9–12] and many others].

T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_6,

It is a known method of analysis and synthesis when nonlinear system can be decoupled into linear and nonlinear parts. If the linear part of the system has the characteristics of low-pass filter and if we apply periodical signal to the system, output signal will have the same base frequency as input signal with damped higher frequencies.

If the amplitudes of higher harmonics are relatively small when compared to the amplitude of the first harmonic, i.e. if filter hypothesis holds, output signal can be approximated by its first harmonic. Mathematically, first harmonic of the output signal, for the sinusoidal input signal $X_m \sin \omega t$, can be expressed by Fourier expressions:

$$\begin{aligned} y_N(t) &\approx Y_{P1} \sin \omega t + Y_{Q1} \cos \omega t \\ y_N(t) &\approx \operatorname{Im}\left\{ \left(Y_{P1} + jY_{Q1}\right) e^{j\omega t} \right\} \end{aligned} \tag{1}$$

$$Y_{P1} = \frac{1}{\pi} \int_0^{2\pi} F(X_m \sin \omega t) \sin \omega t \, d(\omega t) \tag{2}$$

$$Y_{Q1} = \frac{1}{\pi} \int_0^{2\pi} F(X_m \sin \omega t) \cos \omega t \, d(\omega t) \tag{3}$$

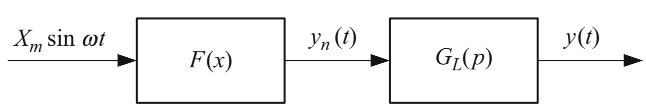

Fig. 1 Actuator represented with decoupled nonlinear F(x) and linear parts $G_L(p)$, p = d/dt

where Y_{P1} and Y_{Q1} are first Fourier coefficients. Describing function is the ratio between first harmonic of the output signal and input signal in complex form:

$$G_N(X_m) = P(X_m) + jQ(X_m) = \frac{Y_{P1}}{X_m} + j\frac{Y_{Q1}}{X_m} \tag{4}$$

where $P(X_m)$ and $Q(X_m)$ are coefficients of the harmonic linearization [2, 9–12] and many others].

Determination of Describing Function

Determination of describing function boils down to the determination of integral expressions for the known static characteristic of the nonlinear part of the system.

There are many conventional nonlinearities for which static characteristics and describing functions are theoretically derived and given in analytical form.

The problem arises when the static characteristic of nonlinear system cannot be analytically expressed or integral expressions cannot be solved. In that case describing function can be determined by experiment or simulation [3–8] or some method of numerical integration [10].

In this work we will use numerical integration in Simulink as given in [10]. The approach is very simple, yet effective. In essence, Eqs. (2) and (3) are directly applied in Simulink on nonlinear element outputs. A simulation scheme adapted from [10] is given in Fig. 2. In this case dead zone nonlinearity is analyzed. Instead of dead zone, any other nonlinearity can be included in model.

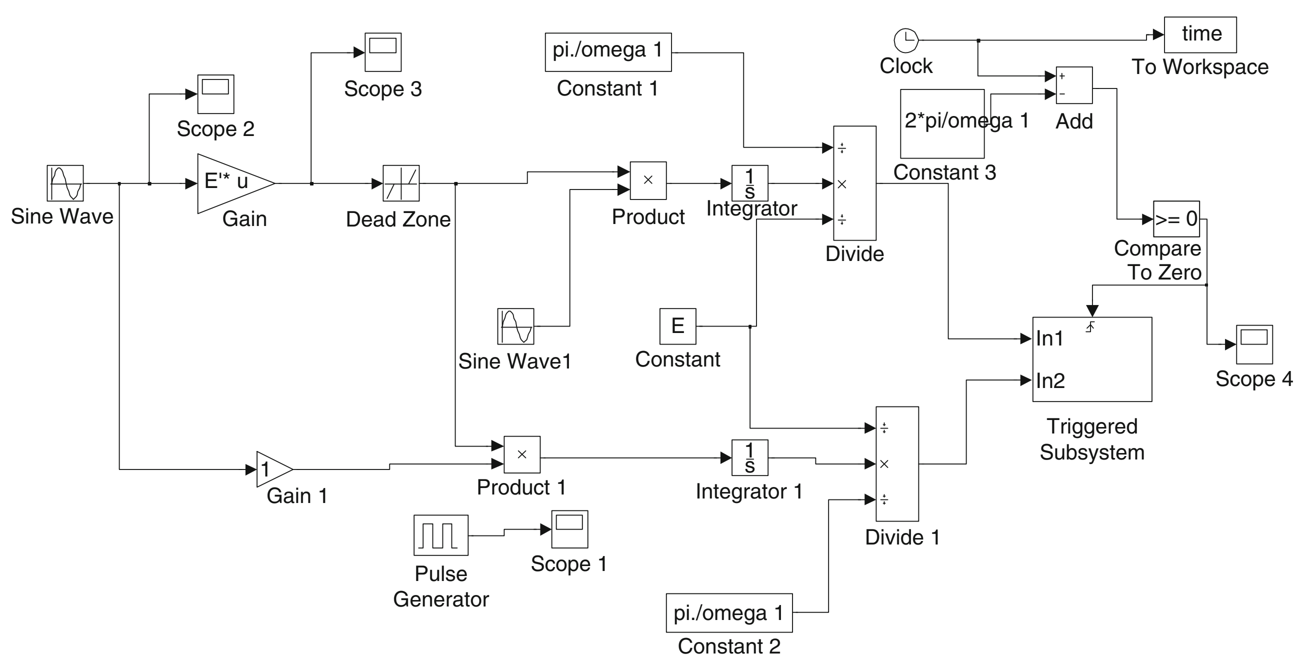

Fig. 2 Simulink model for generating describing function

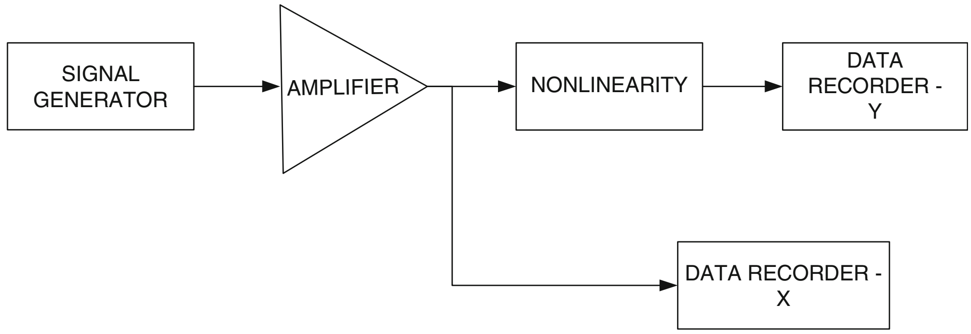

Fig. 3 Data generation and recording

Model is called from Matlab script (adapted from [10] as well). Simulation parameters are passed to Simulink schematic from Matlab script as well. More details about simulation files and describing function recording can be found in [13].

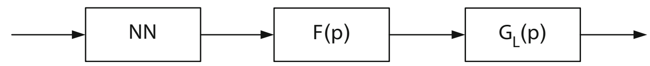

Fig. 4 NN nonlinearity compensation

Neural Network Representation of Odd Symmetric Nonlinearity

In this section we describe simple neural network (NN) representation of odd symmetric nonlinearity. We deal with actuator with architecture shown in Fig. 1. It is important that in practice $y_n(t)$ is measurable. This is often the case because many motor drives and hydraulic drives have nonlinearity in part of their electronic driver and this value can be measured. We then connect an input with changeable amplitude and measure and save inputs and outputs. Once this is done we will use recorded data to train simple neural network in such way that we try to achieve neural network that will have opposite action to nonlinearity. Of course, it is impossible to achieve exact opposite action, but in many cases it is possible to achieve good enough representation to improve nonlinear characteristic. Schematic of data generation and recording is shown in Fig. 3.

In our case datasets X and Y were generated using chirp signal generator with starting frequency 0.1 Hz, final frequency 20 Hz and simulation end time 1,000s with fixed step size 0.001. Odd symmetric nonlinearities are static nonlinearities so frequency really does not have an effect on them but we used chirp signal in order to generate a number of different data points. Final frequency depends on $G_L(p)$ and amplitude of amplification depends on expected input values into nonlinearity. This analysis is made taking into account operating requirements of actuator and final frequency has to be inside damping zone of $G_L(p)$. An example for dead zone is given in [13].

After data is recorded, one can use dataset Y as network input and dataset X as network output for training. There are many tools available for neural network training. Here, Matlab neural networks toolbox was used. Feed forward network had two layers, first layer with seven nodes and sigmoid tangent activation function and one node in output layer with linear gain activation. Network was trained for 700 epochs with gradient descent with adaptive learning rule backpropagation. An example for dead zone is given in [13]. The same network architecture was used for all nonlinearities described in this paper. Choice of number of nodes and activation functions is heuristic and depends on required precision.

With trained neural network we can compensate for nonlinearity as shown in Fig. 4

where NN stands for neural network and F(p) is nonlinearity. The idea is that neural network compensates for some effects of nonlinearity since neural network is trained to act as inversion of nonlinear function.

However, realizing neural network sometimes can be complicated. One possibility is to replace the neural network with its describing function. We will use numerical integration as given in [10]. More details are given in [13].

This script will result in graphic presentation of describing function in 3D. Since nonlinear element is odd and time independent so it is neural network. Thus, we need only 2D representation of describing function. Furthermore, we can represent this graphic describing function by polynomial $G_{NN}(x)$:

$$G_{NN}(x) = a_n x^n + a_{n\text{-}1} x^{n\text{-}1} + \ldots + a_1 x + a_0 \qquad (5)$$

Polynomial approximation is easier to realize than neural network, i.e. we can use simpler hardware to do so.

Describing function of neural network and its third order polynomial representation for dead zone with start and end of dead zone equal to 1 are shown in Fig. 5. NN training data was obtained using scheme from Fig. 3 with amplification of 5. Neural network describing function and its third order polynomial approximation for saturation with upper and lower limit equal 0.5 are shown in Fig. 6. Amplification for data recording was 1.

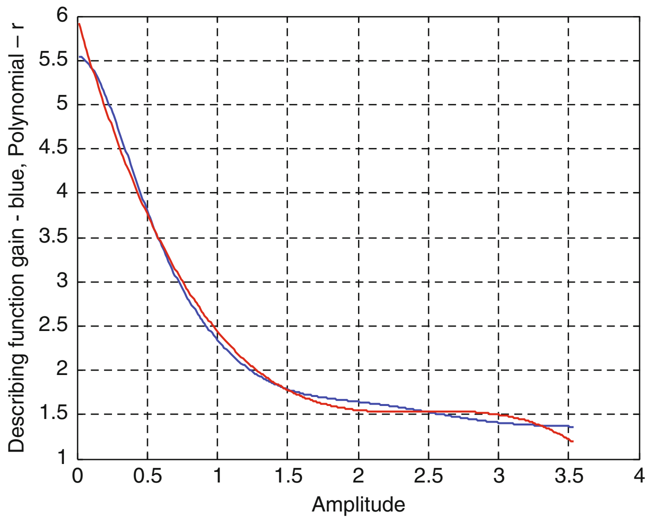

Fig. 5 Neural network describing function and its polynomial approximation for dead zone

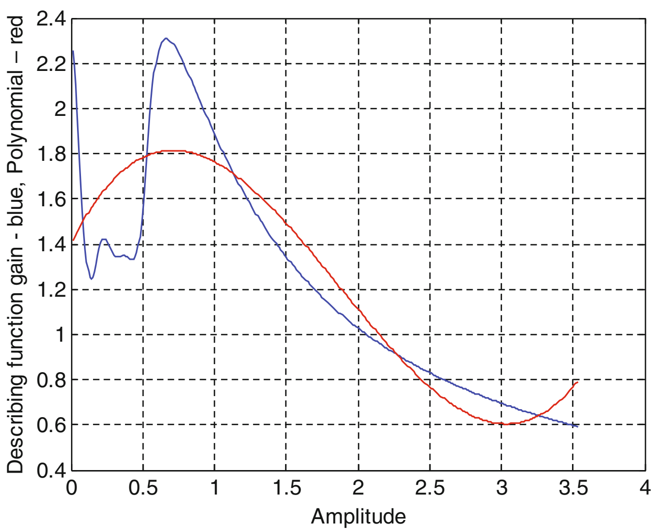

Fig. 6 Neural network describing function and its polynomial approximation for saturation

Neural network describing function and its fifth order polynomial approximation for dead zone with saturation with upper and lower limit equal 1 with start and end of dead zone equal to 0.3 are shown in Fig. 7. Amplification for data recording was 1.5.

Neural network describing function and its fourth order polynomial approximation for friction y = sign(x)[abs(x) + 0.5] are shown in Fig. 8. Amplification for data recording was 3.

We will now see how this system performs for simple closed loop circuit. Simulink simulation model is shown in Fig. 9.

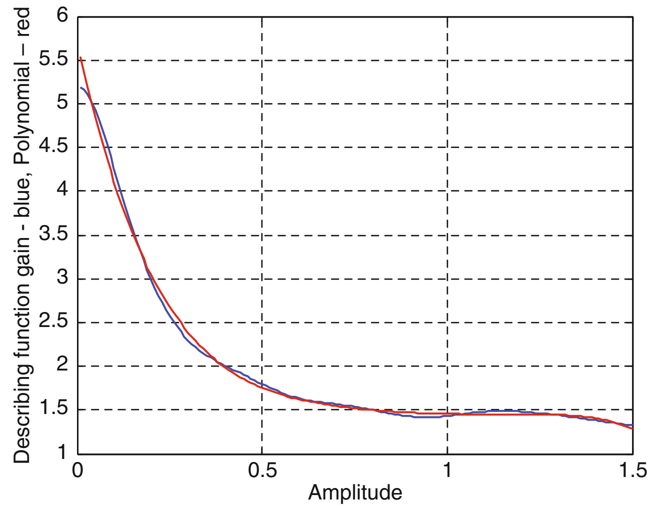

Fig. 7 Neural network describing function and its polynomial approximation for dead zone with saturation

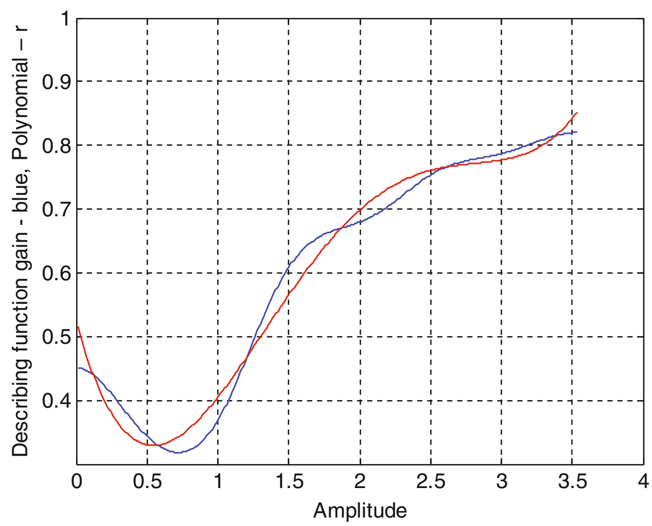

Fig. 8 Neural network describing function and its polynomial approximation for friction

Simulation results for compensated deadzone for step input are shown in Figs. 10, 11, 12 and 13.

Output of non-compensated system is shown in black, response of system compensated with neural network is shown in blue and response of system compensated with polynomial approximation of neural network in red. It can be seen that compensated system has better response and reaches the reference value faster in all cases but compensated friction. In case of friction compensated system reaches reference value slower but there is no overshoot.

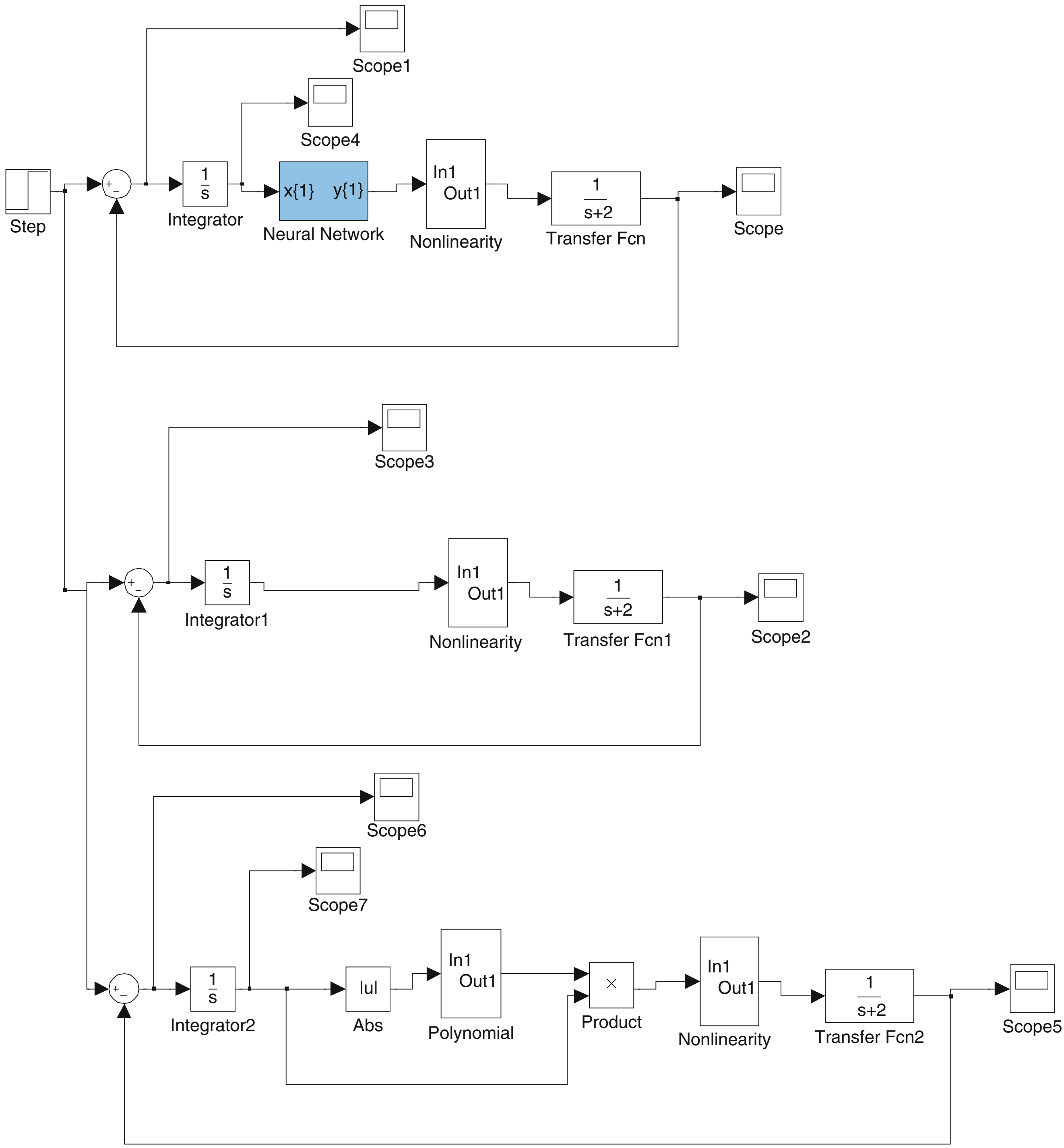

Fig. 9 Simulink simulation model

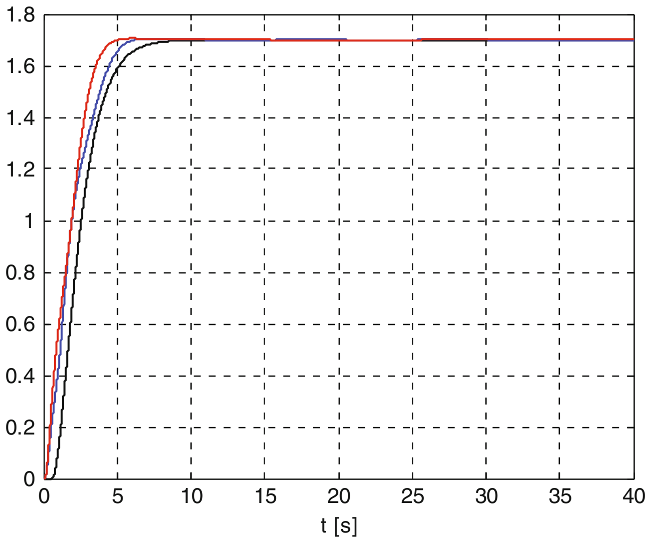

Fig. 10 Simulation responses for compensated dead zone for step input 1.7

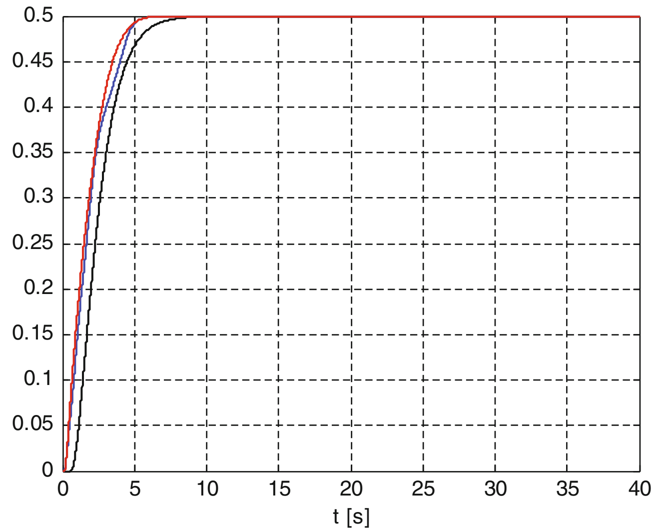

Fig. 12 Simulation responses for compensated dead zone with saturation for step input 0.5

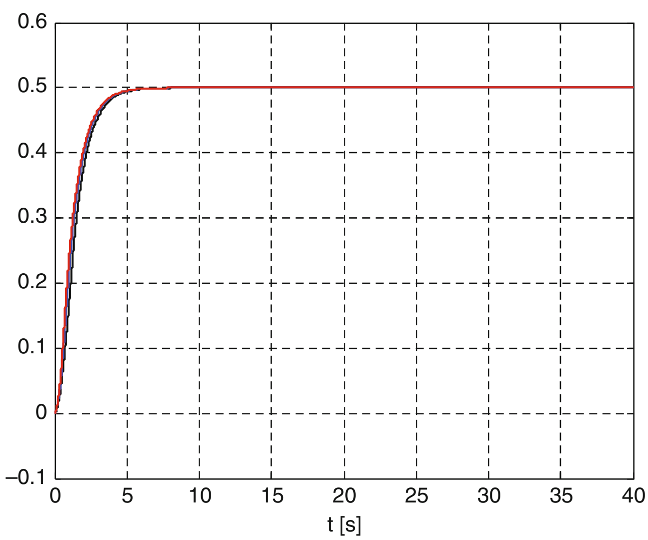

Fig. 11 Simulation responses for compensated saturation for step input 0.5

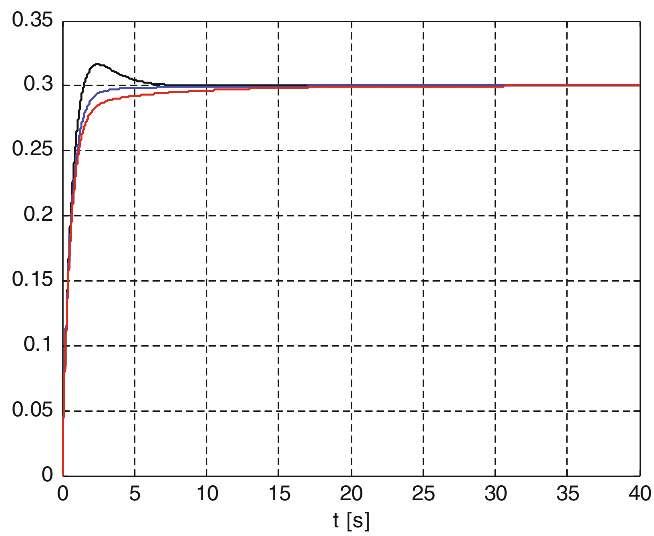

Fig. 13 Simulation responses for compensated friction for step input 0.3

Stability Analysis of NN Compensated Odd Symmetric Nonlinear Actuator

It is clear that when we make compensation of nonlinearity with neural network or neural network polynomial approximation in essence we have a new nonlinearity as shown in Fig. 14.

With compensated nonlinearity we can record describing function using method given in section "Determination of Describing Function". Recorded describing functions of compensated nonlinearities from section "Neural Network Representation of Odd Symmetric Nonlinearity" are given in Figs. 15, 16, 17, and 18.

Block schematic of closed loop system with compensated nonlinearity is shown in Fig. 19.

Characteristic equation of closed loop system with compensated nonlinearity as shown in Fig. 19 can be written as

$$s^2 + Ks + G = 0 \tag{6}$$

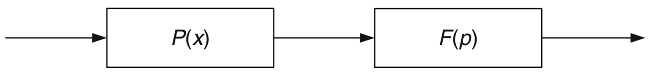

Fig. 14 Compensated nonlinearity

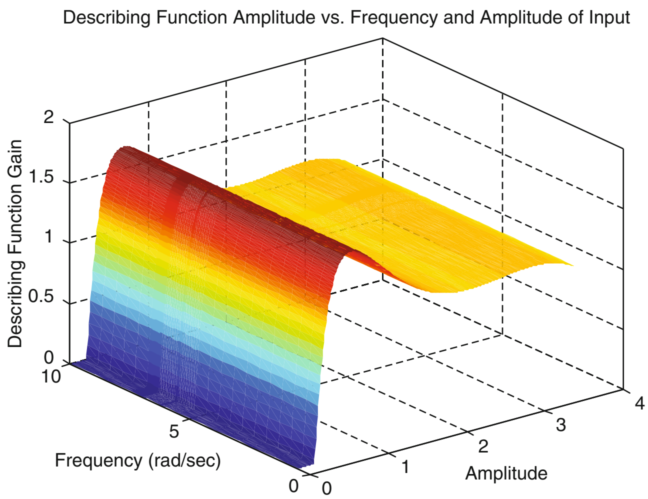

Fig. 15 Describing function—compensated dead zone

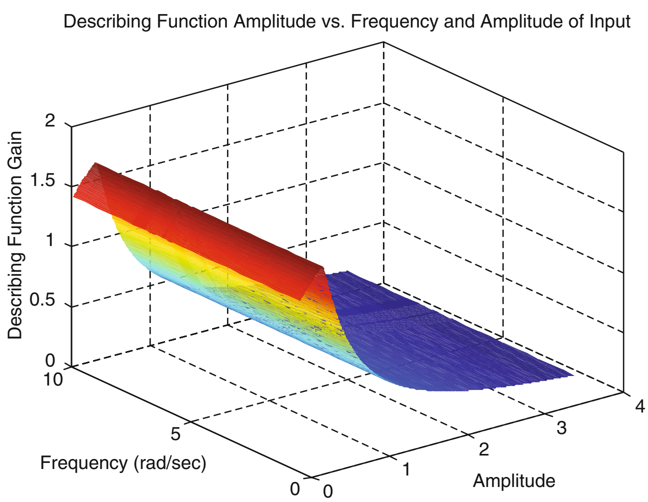

Fig. 16 Describing function—compensated saturation

where G is describing function of compensated nonlinearity and K is linear parameter system of actuator transfer function represented by

$$\frac{1}{s+K} \tag{7}$$

Once we have describing function we can use any stability criterion we use for linear systems. By Hurwitz criterion the system will be stable if

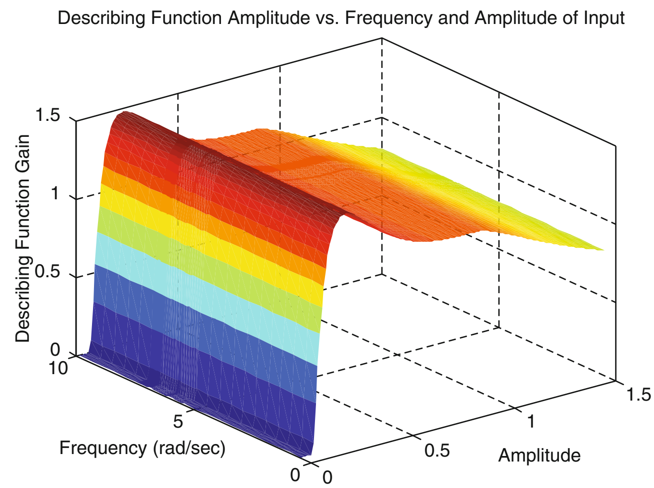

Fig. 17 Describing function—compensated dead zone with saturation

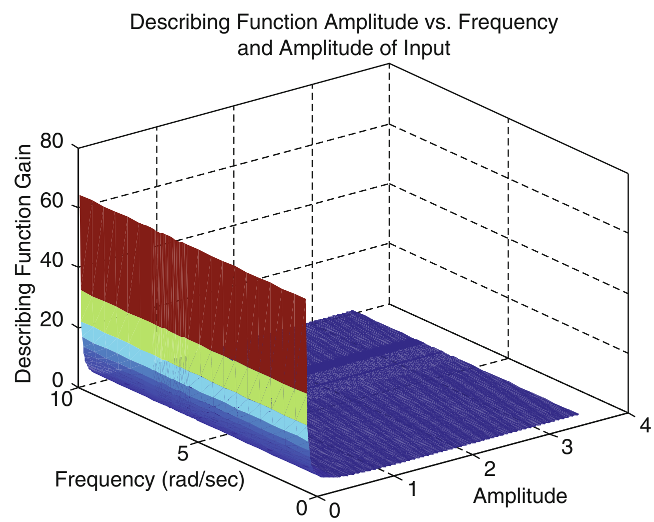

Fig. 18 Describing function—compensated friction

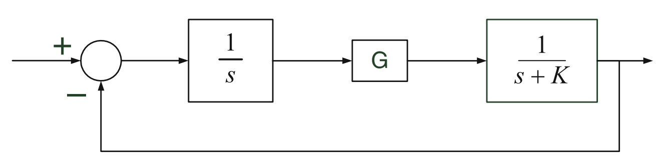

Fig. 19 Block schematic of closed loop system with compensated nonlinearity

$$KG > 0 \tag{8}$$

Since K is always positive, system will be stable if G $>$ 0. In cases described here that is always the case, thus the system is stable. The same analysis can be conducted with other types of nonlinearity.

Conclusion

Paper gives the procedure for training neural network to act as a compensator for odd symmetric nonlinearities. It is shown how to record the describing function of such neural network. In cases that available hardware cannot deal with neural network we can use neural network describing function polynomial approximation to control the systems with odd symmetrical nonlinearities.

Finally, a simple procedure for analyzing stability of such systems is given.

Acknowledgment Research was partially supported by HZZZ grant 09/193 Fuzzy Logic Adaptive Elastic Controller.

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Stream Collision Management in MIMO Ad-Hoc Network Sustaining the Lower Bound of QoS

Viktor Zaharov, Angel Lambertt, and Olena Polyanska

Abstract

The ad hoc wireless network that operates in the rich multipath propagation environment is considered. It is supposed that the node-to-node communication link are performed with multi-element antennas and MIMO spatial multiplexing transmitting-receiving strategy in use. The signal-to-interference-plus-noise-ratio (SINR) in the presence of interpath interference is analyzed. The cooperation among transmitted node is used to avoid the stream collision through the concurrent paths when the performance criteria is the quality of service (QoS) of peer-to-peer links is considered. The revised water pouring algorithm (RWPA) that helps to redistribute the power among the transmitted antennas according to QoS performance criteria is discussed. The proposed approach of the stream collision management allows to avoid the interpath interference as well as to maintain at least lower bound of QoS. The simulation part analyzes scenario with two pairs of node-to-node communication links.

Keywords

Ad hoc networks • Array signal processing • Channel state information • MIMO • Multiuser communications • Spatial multiplexing • Water pouring algorithm

Introduction

Wireless ad hoc networks is basically peer-to-peer network of hosts that have not fixed communication infrastructure [1]. Extending MIMO concept to ad hoc network applications by using the medium access protocols such as IEEE 802.11n helps to achieve much higher spectral efficiencies than that of the traditional single-input-single-output (SISO) omnidirectional antennas nodes networks providing higher data throughput and improving system performance [2, 3].

A serious challenge is how to efficiently allocate the transmission powers among multiple antenna elements for each peer to peer link maximizing network throughput in the presence of mutual interfering paths (interpath interference). A lot of efforts in the literature have been undertaken to solve this problem. For example, multiuser water-pouring algorithm (WPA) is described in [4], where the interference path at the receiver can be suppressed with "whitening of the channel matrix" by matrix inversion operation. The nonco-operative maximization of mutual information in the vector Gaussian interference channel via game theory is considered in [5]. Among other, some suitable solutions have been also discussed in [1, 2, 6]. The rigorous solution, as a rule, accompanies the high-priced computational procedure. However, sometimes less tense criteria than overall through-put are more essential for practical applications, for

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_7,

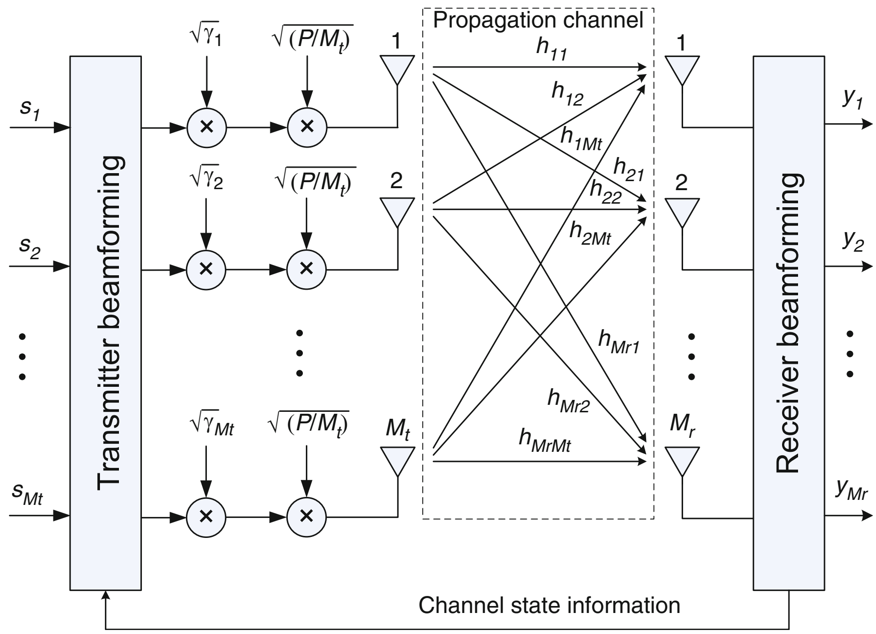

Fig. 1 Transmitter-receiver node pair in MIMO ad hoc network

example, when the QoS of peer-to-peer links plays the dominant role.

In this paper we consider the performance of node-to-node communication link in the presence of interpath interference for spatial multiplexing MIMO physical layer when multiple independent data streams are transmitted using channel state information on the transmitter part (CSIT). We propose and analyze inexpensive approach that helps to avoid the stream collision through the concurrent paths and in the same time to maintain the acceptable QoS for each peer-to-peer communication pare. The revised water pouring algorithm (RWPA) that helps to succeed our criteria is considered.

SINR in the Presence of Interpath Interference

A typical scenario in MIMO ad hoc networks is where the numerous nodes communicate simultaneously by using the same spectrum band and exploiting the propagation channel diversity. Let us consider an ad hoc network with simultaneously communicating transmitter-receiver node pairs, as Fig. 1 shows. Each node is equipped with M_t transmit antennas and M_r receive antennas. The transmitted signal $\mathbf{s}\in\mathbb{C}^{M_t\times 1}$ is column vector with i.i.d. standard Gaussian entries s_i, $i = 1, 2, \ldots, M_t$, and its covariance matrix is $E\{\mathbf{s}\mathbf{s}^\dagger\} = (P/M_t)\Upsilon$, where $\Upsilon = diag\{\gamma_1, \gamma_2, \ldots, \gamma_{M_t}\}$, is a power allocation matrix, P is a total power allocated to a transmitted node, and $\sum_{k=1}^{K}\gamma_i = M_t$.

All nodes communicate in the Rayleigh fading propagation channel with a rich scattering environment, and each transceiver-receiver pair attempts to avoid the interference through the use of multiple receiver antennas.

We introduce the channel matrix for the arbitrary transmitter-receiver pair as

$$\mathbf{H} = \mathbf{R_r}^{1/2}\mathbf{H}_{\mathcal{N}}\mathbf{R}_t^{1/2}, \tag{1}$$

where $\mathbf{H}_{\mathcal{N}}\in\mathbb{C}^{M_r\times M_t}$ is the i.i.d. complex values $\mathcal{CN}(0,1)$, which are the collection of all channel propagation coefficients, $\mathbf{R}_r$ and $\mathbf{R}_t$ are receiver and transmitter correlation matrix, respectively [7]. Assuming that $\mathbf{R}_r$ is the identity matrix, we consider the case with correlation at the transmitter side only. For the uniform linear array, the correlation coefficient r_{ij} between ith and jth transmitting antennas is [3]

$$r_{ij} = J_0[2\pi(i-j)d/\lambda] \tag{2}$$

where $J_0(x)$ is the zero order Bessel function of the first kind, and d/λ is an inter-element distance to the carrier wavelength ratio.

Furthermore, we ignore the large scale propagation attenuation of the received signal, assuming that $\sum_{j=1}^{M_t} E\left\{\left|h_{ij}\right|^2\right\} = M_t$, $i = 1, 2, \ldots, M_r$, where $E\{\cdot\}$ is the expectation operator, and h_{ij} are the elements of the matrix $\mathbf{H}$. This implies that each of the receiver antenna receives a power, which is equal to the total transmitted power P.

Let us consider the communication scenario with desired link, where one of the node transmits (desired transmitted node) and other node receives (desired receiving node) the data, and K interferer links around. The desired receiving node receives the signal of interest $\mathbf{s}^{(d)}$ as well as K interferer signals $\mathbf{s}^{(k)}$; $k = 1, 2, \ldots, K$.

The set of the channel matrices related to the desired receiving node is $\{\mathbf{H}^{(d)}, \mathbf{H}^{(1)}, \mathbf{H}^{(2)}, \ldots, \mathbf{H}^{(k)}, \ldots, \mathbf{H}^{(K)}\}$. Let the singular value decompositions (SVD) of the matrices $\mathbf{H}^{(d)}$ and $\mathbf{H}^{(k)}$ are

$$\mathbf{H}^{(d)} = \mathbf{U}^{(d)}\mathbf{\Sigma}^{(d)}\mathbf{V}^{(d)\dagger};\ \mathbf{H}^{(k)} = \mathbf{U}^{(k)}\mathbf{\Sigma}^{(k)}\mathbf{V}^{(k)\dagger}, \tag{3}$$

where $\mathbf{U}^{(d)}, \mathbf{U}^{(k)} \in \mathbb{C}^{M_r \times M_r}$, $\mathbf{V}^{(d)}, \mathbf{V}^{(k)} \in \mathbb{C}^{M_t \times M_t}$, and $\mathbf{\Sigma}^{(d)}, \mathbf{\Sigma}^{(k)}$ are corresponding receiver and transmitter precoding matrices with the orthonormal properties, and the singular values matrices.

The desired receiving node output vector in the presence of K interferer signals is

$$y = \sqrt{P^{(d)}}\mathbf{U}^{(d)\dagger}\mathbf{H}^{(d)}\mathbf{V}^{(d)}\mathbf{s}^{(d)} + \sum_{k=1}^{K}\sqrt{P(K)}\mathbf{U}^{(d)\dagger}\mathbf{H}^{(k)}\mathbf{V}^{(k)}\mathbf{s}^{(k)} + \mathbf{U}^{(d)}\mathbf{n}. \tag{4}$$

Substituting (3) into (4) and afterwards using the orthonormal properties of precoding matrices we rewrite (4) as

$$y = \sqrt{P^{(d)}}\sum\nolimits^{(d)}\mathbf{s}^{(d)} + \sum_{k=1}^{K}\sqrt{P(K)}\mathbf{U}^{(d)\dagger}\mathbf{U}^{(k)}\sum\nolimits^{(k)}\mathbf{s}^{(k\dagger)} + \mathbf{U}^{(d\dagger)}\mathbf{n}, \tag{5}$$

where the first term is the desired signal and the second term is an interfering signal in the output, and $\mathbf{n}$ the AWGN vector with the variance σ_n^2. Taking into account that $E\{\mathbf{s}^{(d)}\mathbf{s}^{(k)\,\dagger}\} = E\{\mathbf{s}^{(m)}\mathbf{s}^{(k)\,\dagger}\}_{m \neq k} = 0$, the overall average SINR in the output of the MIMO receiver in the spatial multiplexing mode regarding to each partial virtual subchannel yields

$$SINR_i = \frac{P^{(d)}\gamma_i{}^{(d)}\lambda_i{}^{(d)}}{\sum_{k=1}^{K} P^{(k)}\mathbf{u}_i{}^{(d)\dagger}\mathbf{U}^{(k)}\mathbf{\Lambda}^{(k)}\Upsilon^{(k)}\mathbf{U}^{(k)\dagger}\mathbf{u}_i{}^{(d)} + \sigma_n{}^2}. \tag{6}$$

where $\mathbf{u}_i^{(d)}$ and $\lambda_i^{(d)}$ are ith eigenvector and ith eigenvalue of the matrix $\mathbf{H}^{(d)}$, respectively.

As (6) shows, the level of interfering signal in the output of the ith virtual subchannel is completely determined by the product $\mathbf{u}_i{}^{(d)\,\dagger}\mathbf{U}^{(k)}$. When $\mathbf{u}_i{}^{(d)\,\dagger}\mathbf{U}^{(k)} = \mathbf{0}$, the vector $\mathbf{u}_i{}^{(d)}$ is orthonormal to all columns of the matrix $\mathbf{U}^{(k)}$, meaning no stream collision, i.e., the non-interfering scenario is running. However, $\mathbf{u}_i{}^{(d)\,\dagger}\mathbf{U}^{(k)} \neq \mathbf{0}$ indicates that some path of the desired link concurs with some path of the interferer link. For example consider scenario shown in the Fig. 2, where $\mathbf{u}_i{}^{(d)\,\dagger}\mathbf{U}^{(k)} = \mathbf{0}$, $i = 1, 2, 3$, and $\mathbf{u}_4{}^{(d)\,\dagger}\mathbf{U}^{(k)} = [1\ 0\ 0\ 0]$, meaning that fourth path of desired link is concurs with the first path of interferer link, and corresponding streams collision occurs. Hence, when the number of collision is L, the expression of average SINR for ith virtual channel (6) can be rewritten as

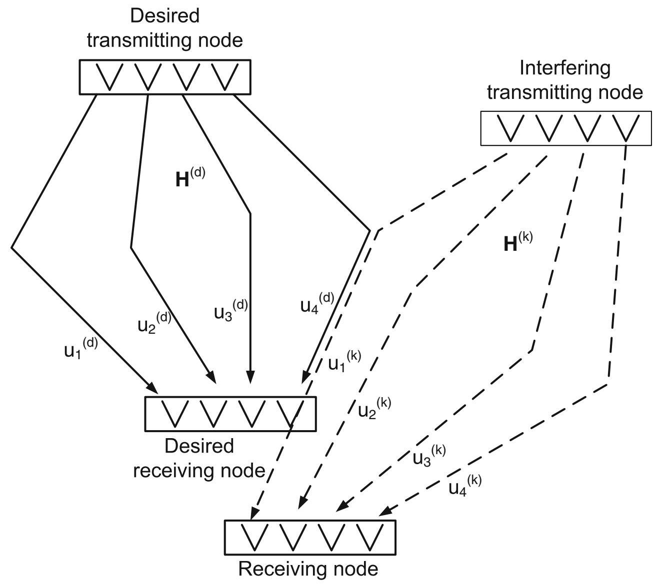

Fig. 2 MIMO communication scenario with collision of two streams

$$SINR_i = \frac{P^{(d)}\gamma_i{}^{(d)}\lambda_i{}^{(d)}}{\sum_{j=1}^{L} P^{(k)}\gamma_j{}^{(k)}\lambda_j{}^{(k)} + \sigma_n{}^2}, \tag{7}$$

where L is a number of nonorthogonal paths between $\mathbf{u}_i{}^{(d)}$ and $\mathbf{U}^{(k)}$, or number of stream collisions.

As follows from (7), the more jointly nonorthogonal virtual channels the higher the level of interference and as a consequence, the lower ratio of SINR in the output of ith virtual channel. The total impact of kth interfering link into overall average SNIR of the desired link can be estimated by forming the product $\mathbf{U}^{(d)\,\dagger}\mathbf{U}^{(k)}$. For example, for the scenario shown in Fig. 2 the result is 4×4 matrix with all zero elements except one with the unit value in the crossing of first column and fourth row.

Stream Allocation Strategies in the Presence of Interpath Interference

Obviously that the non-interferer scenario for the desired link is when the matrix $\mathbf{U}^{(d)\,\dagger}\mathbf{U}^{(k)}$ has all zero elements. It can be achieved by suppression of all interferer paths on the desired receiver side using spatial-temporal processing [8, 9]. However, it is almost useless when interfering and desired streams are not spatially resolved; but even if they are spatially resolved the spatial-temporal processing requires enormous computational work diminishing the power efficiency of affected node.

We propose other solution, where the nonzero elements of the matrix $\mathbf{U}^{(d)\,\dagger}\mathbf{U}^{(k)}$ are forced to zero by discarding those virtual channels which causes the stream collision. This approach does not require big computational efforts (that could be rigorously found in the full version of paper), however, it requires the transmitted power redistribution in the transmitter side of the link. We discuss the virtual path discarding strategy based on the game-theoretic framework [6], where the payoff function of the game is the certain level of QoS of each player, i.e. $C_j \geq C_{min}$, where C_{min} is a link capacity that still able to maintain a certain level of QoS. The players are the peer-to-peer links with corresponding channel eigenvalues entries, and available transmitted power (further without loose of generality we set $P^{(d)} = P^{(k)} = 1$). Furthermore, some sort of cooperations among transmitted nodes are implicated.

Let us consider the scenario where desired transmitting and receiving nodes try to establish the communication link in the presence of already operating K interfering links. To avoid the stream collisions the following operations should be done on the desired transmitter side to satisfy the payoff function:

1. Send the pilot signal and receive back the matrices $\mathbf{U}^{(k)}$ through the reverse channels, then compute the product $\mathbf{U}^{(d)\dagger}\mathbf{U}^{(k)}$, $k = 1, 2, \ldots, K$, and estimate which virtual paths already in use.
2. Using WPA compute the power allocation and channel capacity $C^{(d)}$ if only "clear" virtual paths will be involved to transmit the data.
3. If $C^{(d)} \geq C_{min}$, then discard the eigenvalues that cause the stream collisions and start to transmit the data.
4. If $C^{(d)} < C_{min}$, estimate which virtual sub-channel can be borrowed from some interferer links to achieve C_{min}. For this, send demand to interferer link through concurrent paths, inquiring about possibility to borrow the concurred path.
5. Interferer node receives the demand and recompute its capacity excluding the requested path. If $C^{(k)} \geq C_{min}$ the kth node send the positive confirmation through the reciprocal concurrent path to the desired node, then discard this path from the transmission, and recalculate new power allocation coefficients. If $C^{(d)} \leq C_{min}$ the request is denied.
6. If desired node obtains the required path, it starts to transmit data, if request is denied, it tries to send the request to other interferer links if someone. If all concurrent paths have denied the request the desired node is getting idle, till propagation condition would be more favorable.

When some virtual path is discarded, the power distribution strategy should be revised. It is well know that for the MIMO non-interfering scenarios to distribute the transmitted power optimally between transmitted antennae the WPA provides the optimum solution [10]. In the presence of interpath interference, and criteria QoS in use the conventional WPA should be slightly revised including the following improvements:

1. The eigenvalues of interferer virtual paths should be determined and discarded.
2. The matrix of eigenvalues $\mathbf{\Lambda}$ should be rearranged, and new rank, $r = r$–L is redefined, where L is a number of discarded eigenvalues.

Further, it is running similarly to WPA. Revised version of WPA we call the revised WPA or RWPA. The computational work to adjust the power allocation factors using RWPA is just about $O(M_tL)$. The power redistribution among transmitted antennae either desired or interferer node yields to the following link capacity

$$C^{d(k)} = \max_{\Sigma_{j=1}^{r-L}\gamma_j = M_t} \sum_{j=1}^{r-L} \log\left(1 + \beta\gamma_j\lambda_j\right). \tag{8}$$

The proposed approach is a simple way to avoid the interpath interference. Despite the total network throughput could be far from the optimum (because the virtual sub-channels with the good propagation condition could be discarded), it helps to maintain the QoS of each link above the lower limit, C_{min}.

Simulation Result

We consider scenario with two transceiver pairs of nodes, all equipped with uniform linear array (ULA) antennas, $M_t = M_r = 4$, $\lambda/2$ space element distance, and the signal-noise ratio in the receiver is 20 dB. The desired link operates in the presence of kth interfering node, as Fig. 2 shows. The channel matrices $\mathbf{H}^{(d)}$ and $\mathbf{H}^{(k)}$ have been generated and their eigenvalues matrices are computed. The result is $\mathbf{\Lambda}^{(d)} = diag\{35.5181\ \ 3.4111\ \ 1.0148\ \ 0.1743\}$ and $\mathbf{\Lambda}^{(k)} = diag\{32.1907\ \ 2.1954\ \ 0.6920\ \ 0.1597\}$ that indicate that both matrices have a full rank. The potential capacities of desired and interfering links in the non-interferer scenario according to (8) are 15.4303 $b/s/Hz$ and 14.2346 $b/s/Hz$, respectively.

We discuss scenario when interferer link already in use, but desired link still idle. The power allocation coefficients for kth interfering node are computed using the conventional WPA in the non-interferer scenario. WPA converged after the first iteration, and the power allocation diagram depicted in Fig. 3, where $n = 1, 2, 3, 4$ is a virtual channels, and the dark areas related to the positive values of γ_n. In the first interfering scenario we suppose that desired nodes pair try to establish the link. Firstly, the transmitter transmit the pilot signal, and the stream collision occurs between fourth desired and first interferer paths as Fig. 2 shows. The interferer receiving node detect the collision, and, because of the reciprocity of the channel, transmit the matrix $\mathbf{U}^{(k)}$ to the

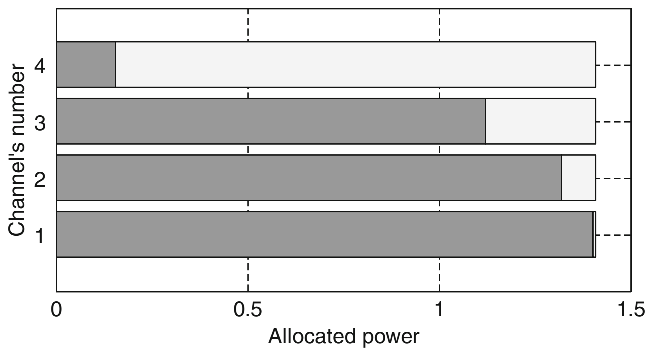

Fig. 3 MIMO link power allocation for non-interfering scenario

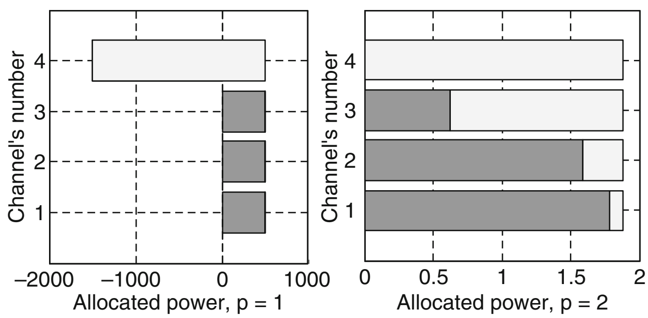

Fig. 4 MIMO interferer link power allocation with RWPA

desired link. The desired transmitter find the product $\mathbf{U}^{(d)\dagger}\mathbf{U}^{(k)}$ and determines that fourth path could cause the stream collision with the first interferer path, and estimate $C^{(d)}$ assuming that fourth path is excluded from its own transmission, and the result is $C^{(d)} = 15,\ 4267$ $b/s/Hz$. If $C^{(d)} \geq C_{min}$ then the fourth path is discarded, the transmission power is rearranged among antennae with SWPA, and desired link start to transmit by using three "clear" paths.

However, if $C^{(d)} < C_{min}$, then the desired transmission node try to borrow the first path from the interferer node sending the request by using its fourth path. The interferer node receives the request and recalculate the capacity assuming that the first path would be discarded, and the result is $C^{(k)} = 7.6490$ $b/s/Hz$. If request is succeeded, i.e., $C^{(k)} \geq C_{min}$ in the absence of the first path, then desired node start to transmit the data. The kth interfering transmitted node discards the first path of its link in favor of fourth path of desired link and then optimally (in terms of channel throughput) redistributes the power among the transmitted antenna elements with SWPA. It turns to the modified eigenvalue matrix $\mathbf{\Lambda}^{(k)} = diag\{2.1954\ 0.6920\ 0.1597\ 0.0\}$, i.e., the first eigenvalue is discarded. SWPA converged after the second iteration, as Fig. 4 shows. However, if request is denied ($C^{(k)} < C_{min}$), then desired link cannot be established due to unable to satisfy the payoff criteria. In the second interfering scenario we consider the case when the interferer node borrows the fourth path from the desired link. It can be happened when interfering link try to transmit the data when desired link already in use. Firstly, the interferer node compute the potential capacity without first interferer path, and it is $C^{(k)} = 7.6490$ $b/s/Hz$, and if $C^{(k)} < C_{min}$ then it try to borrow the fourth path from the desired link. If discarding of the fourth path results $C^{(d)} \geq C_{min}$, then the request succeed. RWPA recalculate the resulting eigenvalues matrix of the desired link as $\mathbf{\Lambda}^{(d)} = diag\{35.5181\ 3.4111\ 1.0148\ 0.0\}$ and desired and interferer link capacities become $C^{(d)} = 15,\ 4267$ $b/s/Hz$ and $14,\ 2346$ $b/s/Hz$, respectively.

Because C_{min} is a value that very dependable on applications we just estimate the partial and joint capacities for three presented scenarios. Using (8) for both desired and interfering link the total capacity of non-interferer scenario is $C^d + C^k = 15.4303 + 14.2346 = 29.6648$ $b/s/Hz$, the first scenario yields $C^d + C^k = 15.4303 + 7.6490 = 23.0792$ $b/s/Hz$, and the second one give us $C^d + C^k = 15.4267 + 14.2346 = 29.6613$ $b/s/Hz$. The worst case is when the dominant eigenvalue is discarded. However, the QoS of both links could be still acceptable.

Conclusions

We consider the stream management strategy for MIMO ad hoc network links in the presence of interpath interference where cooperative transmission strategy among nodes is used and the performance criteria is QoS of peer-to-peer links. We analyzed the SINR for each virtual channel of the receiving nodes. It leads to the receiver precoding matrices $\mathbf{U}^{(d)\dagger}\mathbf{U}^{(k)}$ product that provides information about the concurrent virtual transmission data streams. Inexpensive approach to avoid the interpath interference when QoS criteria in use is proposed. The node transmitting power is adjusted by revised water pouting algorithm (RWPA). Proposed stream management strategy can simplify significantly the ad-hoc nodes complexity comparing with the case when the whole network capacity should be optimized, in the same time maintaining the required QoS of each peer-to-peer link.

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On Query-Based Search of Possible Design Flaws of SQL Databases

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Abstract
System catalog, which is a part of each SQL database, is a repository where the data in its base tables describes the SQL-schemas (schemas) in the database. The SQL standard specifies the Information Schema, which must contain virtual tables (views) that are created based on the base tables of the system catalog. In this paper, we investigate to what extent one can find information about possible design flaws of a SQL database by querying the tables in its Information Schema and possibly tables in its other schemas. We do this based on a set of SQL database design antipatterns, each of which presents a particular type of database design flaw.

Keywords
SQL database • SQL-schemas • Design flaws • Query-based search

Introduction

Analysis of the code of existing software systems in order to automatically find design flaws in their actual structure is not a new idea. The flaws, which mean violation of some design principle/heuristic, are called *design smells* [1] or *antipatterns* [1, 2]. The elimination of these flaws would facilitate maintenance and reengineering of the systems.

Reverse engineering studies of existing databases show that design flaws in SQL databases are common [3]. Hence, we find it important to study the automation of the search of possible design flaws in the existing SQL databases. Although there are formal relational/SQL database design practices like *normalization* and *orthogonality*, there are also many aspects of the database design that the practices do not address [4, p. 287]. However, publications like [2, 4–6] contain additional design guidelines of SQL databases. Some of the guidelines are represented as patterns [6] or antipatterns [2], which describe good and bad/questionable design principles, respectively. Usually the guidelines are not very strict, meaning that in certain cases there could be exceptions to these.

Market requirements, laws and regulations that influence the business, and technical platforms evolve. Hence, databases must also evolve to continuously meet the needs of their owners and users. The categories of database schema changes are modifications due to requirements changes, database migration, and database refactoring [7]. The quality of database schemas must be as good as possible in order to facilitate the evolution of databases themselves and the evolution of software systems that use the databases. One can improve the quality of a database schema by refactoring it. It means making small changes in a database schema in order to improve the design of the schema but at the same time preserve its behavioral and informational semantics [8]. The first step in a database refactoring process [8] is *Verify that refactoring is needed*. Information about the possible database design flaws is an important input to this step.

The system catalog (also known as *the database catalog*) of a SQL database is a repository that contains description of the SQL-schemas (schemas) in the database (metadata about the database). “Part 11: Information and Definition Schema (SQL/Schemata)” of the SQL standard specifies the Information Schema called INFORMATION_SCHEMA, which

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_8,

must contain virtual tables (views) that are created based on the base tables (tables in short) of the system catalog [9]. The SQL standard also specifies a fictitious schema called DEFINITION_SCHEMA, which must contain base tables that are the basis for the views of the Information Schema. However, SQL-implementations [SQL database management systems (DBMSs)] only have to simulate the existence of the Definition Schema, not implement it in the manner specified in the standard. Therefore, different SQL-implementations could have different structure of the base tables of the system catalog, but should ideally provide the standardized views of the Information Schema.

The goal of the paper is to analyze a set of SQL database design antipatterns in order to find out whether one can detect the occurrences (instances) of the antipatterns in an existing SQL database by querying the tables in the Information Schema and possibly in other schemas of the database by using SQL. Each such antipattern presents a particular type of database design flaw. According to the terminology of Ciupke [10], the result of this kind of query presents a set of *design fragments* (pieces of design) that specify the possible locations of the flaw in the database structure. In our case, each query result must contain at least the schema-qualified names (identifiers) of database objects that *possibly* have the flaw specified in an antipattern. These are references to human experts who must review the results and decide whether there is actually a design problem or not. In order to be able to apply the results in case of as many SQL databases as possible, we try to search the occurrences of antipatterns by querying the standardized Information Schema views, not implementation-specific base tables of the Definition Schema or implementation-specific views based on the Definition Schema. Manual evaluation of the design of existing databases is a time-consuming and error-prone activity. Such queries would allow us to *partially automate* the analysis of the quality of existing databases. There are collections of system catalog queries for database administrators [11] to find information about the structure of databases and in some cases possibly identify certain database design flaws. However, in our view much more systematic treatment of the subject is needed.

The rest of the paper is organized as follows. Firstly, we describe some related work. Secondly, we analyze a set of SQL database design antipatterns in terms of possibilities to discover their occurrences by using queries. Thirdly, we analyze the results. Finally, we conclude and point to the further work with the current topic.

Related Work

There are approaches that use software measures to detect software design flaws based on design models [1] or source code [12]. Salehie et al. [12] propose a two-step process, the first step of which has to find possible spots of flaws and the second step has to identify design flaws by classifying the hot spots based on more precise analysis and filtering. The steps use primitive and complex metrics-based rules, respectively. Other approaches like [10] suggest representing the source code as a typed graph, a set of sets and relations, or a set of propositions and querying the representation of the source code to find design flaws based on structural properties. For instance, Beyer et al. [13] present a software analysis system *CrocoPat* that provides a predicate-calculus based language for querying relations that are extracted from source code. In addition to the detection of design flaws, the analysis of source code can also be used to identify patterns, detect unused code, calculate values of software measures, find out the impact of changes in the code, and generate models that have higher level of abstraction than the source code [13]. One could generate database language statements based on existing databases and try to use these approaches based on the generated statements. However, in this paper, we try to use a simpler approach with fewer steps in order to quickly identify possible database design flaws by querying the existing SQL databases. Beyer et al. [13] show that the use of SQL to search information from a source code has lower performance compared to the use of *CrocoPat*. In addition, the fact that in some SQL DBMSs it is not possible to express queries for transitive closure in basic SQL, further complicates the SQL-based solution.

Our work has some resemblance with the reverse engineering of databases [3] in the sense that we also use existing databases as the input to our analysis and try to find information about their structure.

There are CASE systems, like Oracle™ SQL Developer [14], which allow developers to check whether a conceptual or a logical model of a particular database conforms to a set of design rules and execute transformations to change the models. In addition to the system-defined rules and transformations, one can define additional rules and transformations. These rules are like queries that operate at the model level. In addition, Akehurst et al. [15] show that it is possible to automate SQL database normalization process at the database design model level with the help of metamodelling. All these approaches operate at the model level. One the other hand, in this paper, we investigate whether one can check existing databases without creating database design models by using reverse engineering.

There are algorithms, like TANE [16], which are used to analyze data in the existing databases/data sets in order to identify functional dependencies or approximate functional dependencies between attributes. The results can be used in the context of database normalization in order to improve the design of databases. Similarly, Andritsos et al. [17] propose an approach for discovering duplicate or almost duplicate tuples and attribute values in a large data set that could contain errors, missing values, and duplicate records. The results will be used to group attributes and redefine the schema. Analysis of existing data can be used to detect anomalies to quasi-functional dependencies in XML databases [18]. All these approaches are similar with our work in the sense that we too analyze data in existing databases. However, our approach uses mostly data that is in the base tables of system catalogs of databases.

Self-tuning DBMSs are able to recommend database design changes based on the workload analysis [19]. Similarity with our approach is that the self-tuning systems help us to improve the physical design of databases. However, in our work, we also consider logical database design antipatterns. On the other hand, in this work, we do not investigate how to improve the design but only how to detect possible design flaws.

Query-Based Search of the Occurrences of SQL Database Design Antipatterns

We consider *twelve* SQL antipatterns that are presented by Karwin [2]. We evaluate all the logical (in total *eight* patterns) and physical (in total *four* patterns) design antipatterns presented by Karwin [2]. Sections "Format Comma-Separated Lists" to "Clone Tables or Columns" of the paper describe logical design antipatterns and sections "Use FLOAT Data Type" to "Using Indexes Without a Plan" describe physical design antipatterns. Each such antipattern suggests a solution to a common design problem. However, the solutions often cause new problems and hence represent design flaws. For instance, these could lead to more complicated and less understandable queries and update statements or make it difficult to enforce constraints. For each pattern, we present its name (as the section title) and a short informal description of its proposed solution. We do not discuss how to improve the database design because it is out of the scope of the paper. In addition, we discuss if and how one can find the occurrences of the pattern in an existing database by using one or more queries. Moreover, we informally evaluate the trustworthiness of the results and present the results in section "Analysis of the Results". *False-positive result* means that the result of queries points to the occurrence of an antipattern. However, closer scrutiny shows that in this case there is actually no occurrence of the antipattern in the database design. *False-negative result* means that the queries do not find an occurrence of an antipattern that actually exists in the database.

We assume that databases operate under the *closed world assumption* [20] meaning, among other things, that if a row could appear in a query result at a given time but does not, then the proposition represented by the row is false at that time. We assume that the evaluators of the design of a database have access to the database and enough privileges to execute necessary statements. We have created the queries (SQL SELECT statements) based on PostgreSQL™ 9.2 [21], which is a DBMS that implements the Information Schema. We tested the queries based on a test database, the design of which had deliberate flaws. We do not present the query statements in the paper due to the space restrictions. However, one can find the statements from the file:

http://staff.ttu.ee/~eessaar/files/Design_flaws_queries.pdf

Format Comma-Separated Lists

Description: A multi-valued attribute in a conceptual data model is implemented as a VARCHAR column of a base table in a SQL database. Expected values in the column are strings that contain attribute values, separated by commas or other separation characters.

How to detect the occurrences?: Find all the columns of base tables with the type VARCHAR or CLOB (or their equivalents in the DBMS) and for each found column *c* try to determine, based on the actual values in *c*, whether it contains lists of values. One may try to do it by finding out, whether *c* contains values that themselves contain separation characters. One has to write a procedure/function, which reads data from the *columns* and *tables* views of the Information Schema and based on the collected information constructs SQL SELECT statements for reading data from the base tables. The search conditions of the statements could contain regular expressions.

Always Depend on One's Parent

Description: A hierarchical structure is implemented in a base table by adding a foreign key that refers to a candidate key of the same table.

How to detect the occurrences?: One has to write a query based on the Information Schema views *referential_constraints*, *key_column_usage*, and *constraint_table_usage* to find the referential (foreign key) constraints where the referencing table and the referenced table are the same.

One Size Fits All

Description: A base table has a simple primary key that contains a column with the (case insensitive) name *id* and type INTEGER (or similar). In addition, the primary key values are generated automatically by the system.

How to detect the occurrences?: One has to write a query based on the Information Schema views *table_constraints*, *constraint_column_usage*, and *columns* to find primary key constraints that involve exactly one column, the name of which is *id* and the type of which is an exact numeric type:

NUMERIC, DECIMAL, SMALLINT, INTEGER, or BIGINT (or their equivalents in the DBMS). There are different possibilities for generating primary key values. One could define the primary key column as the identity column. Each identity column is associated with an internal sequence generator [22]. On the other hand, one could use an external sequence generator that is associated with the column by using a trigger procedure or by the default value mechanism. However, it is also possible that requesting a new primary key value from an external sequence generator is a task of an application. It is even possible that the primary key values themselves are generated by an application. One could find out whether a column is an identity column based on the *columns* view. However, for instance, if the primary key values are generated or requested by an application, then it is not possible to detect it by querying the Information Schema views. Therefore, we suggest not to use "automatic value generation" as one of the conditions in the query.

Leave Out the Constraints

Description: Database developers do not define referential (foreign key) constraints. For instance, they could reason that it helps them to reduce performance problems in case of some update operations. However, in this case the enforcement of referential integrity becomes a task of applications. We note that there should be additional antipatterns about leaving out other types of constraints.

How to detect the occurrences?: According to the approach A, we have to find base tables that do not participate in any referential constraint (as the referenced table or as the referencing table) by using a query based on the Information Schema views *referential_constraints*, *key_column_usage*, *constraint_table_usage*, and *tables*.

According to the approach B, we have to find the pairs of base table columns that have the same name and type, but are in separate tables and there is no foreign key constraint that connects these columns. In each pair, at least one of the columns is the primary key column or a unique column of a base table. In order to do this, one has to write a query based on the Information Schema views *key_column_usage*, *table_constraints, referential_constraints*, and *columns*.

Use a Generic Attribute Table

Description: Use a highly generic database design, according to which all or some of the data in a database is represented in terms of *Object_types*, *Objects*, *Attributes*, *Attribute_values*, and *Relationships*.

How to detect the occurrences?: Find base tables, the name of which contains a specific substring (like "object"). The substrings have been suggested as the possible table names in case of the design.

Use Dual-Purpose Foreign Key

Description: Use the same column of a base table T to record references to multiple base tables. In addition, one has to add additional column to T for holding metadata about the parent table, referenced by the current row.

How to detect the occurrences?: Find pairs of different columns of the same base table where the names of the columns are similar (for instance, the Levenshtein distance between the names of the columns is below a certain threshold), one of the columns has an associated check constraint (see section "Specify Values in the Column Definition") that limits values in the column, and another column does not participate in any referential constraint as the referencing column. The relevant Information Schema views would be *tables*, *columns, check_constraints, constraint_column_usage, domain_constraints*, *column_domain_usage*, *key_column_usage*, and *referential_constraints*.

Create Multiple Columns

Description: Create multiple columns with the same type and similar name in a base table in order to implement a multi-valued attribute of an entity type.

How to detect the occurrences?: Find pairs of different columns of the same base table that have the same type. In addition, after the removal of numbers from the names of the columns, the names must be equal in case of each pair. One has to write a query based on the Information Schema views *columns* and *tables*.

Clone Tables or Columns

Description: Split a base table horizontally into multiple smaller base tables based on the distinct values in one of the columns of the original table (Clone Tables). A variation is to split a base table column into multiple columns based on the values in some other column (Clone Columns). Each such newly created table/column has the name, a part of which is a data value from the original tables.

How to detect the occurrences?: Clone Tables: Find pairs of different base tables, in case of which both tables have the same ordered set of pairs of column names and data types. In addition, after the removal of numbers from the names of the tables, the names must be equal in case of each pair.

Clone Columns: Find pairs of different columns of the same base table where the types of the columns are the same.

After the removal of numbers from the names of the columns the names must be equal in case of each pair.

In both cases one has to write a query based on the Information Schema views *columns* and *tables*.

Use FLOAT Data Type

Description: Use the approximate numeric types FLOAT, REAL, and DOUBLE PRECISION (or their equivalents in the DBMS) everywhere you need fractional numeric data. These types would probably encode a real number in a binary format according to the IEEE 754 standard. Hence, the results of calculations with the values that have one of these types can be inexact because out of necessity some numbers must be rounded to a very close value [2].

How to detect the occurrences?: One has to create a query based on the Information Schema view *columns* in order to find the columns of base tables that have an approximate numeric type.

Specify Values in the Column Definition

Description: Specify valid data values in the column definition (in addition to specifying the type of the column) by using, for instance, check constraints or enumeration types. The needed check constraint can be associated directly with a table or could be associated with a domain that is used to specify one or more columns.

How to detect the occurrences?: Find the columns of base tables, which have an associated check constraint that specifies possible values in the column. One has to write a query based on the Information Schema views *check_constraints* and *constraint_column_usage*. In addition, one has to find the columns of base tables that have been defined by using a domain, the specification of which includes a check constraint that specifies possible values in columns. One has to write a query based on the Information Schema views *tables*, *domain_constraints*, *column_domain_usage*, and *check_constraints*.

Assume You Must Use Files

Description: Store images and other media as files outside the database. Store in the database only paths to the files.

How to detect the occurrences?: Find all the columns of base tables with the type VARCHAR or CLOB (or their equivalents in the DBMS) and for each found column *c* try to determine, based on the actual values in the column, whether *c* contains paths to the files. One has to write a procedure/function that reads data from the *columns* and *tables* views of the Information Schema and based on the collected information constructs SQL SELECT statements for reading data from base tables. The search conditions of the statements could contain regular expressions.

Using Indexes Without a Plan

Description: Database developers and administrators might forget to define indexes or define too few indexes. They could also create too many indexes or could create indexes that are not useful. In addition, developers could write queries that no index can help.

How to detect the occurrences of the pattern?: The SQL standard does not specify indexes [22] and hence one cannot ask information about indexes from the Information Schema.

Analysis of the Results

In case of 11 antipatterns (91.7 % of the analyzed patterns), we found at least one approach for detecting their occurrences by using queries based on the Information Schema. The results present "hot spots" according to the terminology of Salehie et al. [12]. False-negative results are possible in case of all the 11 antipatterns. False-positive results are not possible in case of *Always Depend on One's Parent* and *Specify Values in the Column Definition* but are possible in case of other nine antipatterns. In case of these two antipatterns the search is based only on the existence of a declarative constraint. If the constraint does exist, then it points to the occurrence of the antipattern. The possibility of false-positives means that the identified design fragments must be reviewed by human experts. The possibility of false-negatives means that the queries cannot be the only mean to analyze the design of existing databases.

In case of *Format Comma-Separated Lists*, *One Size Fits All*, *Leave Out the Constraints* (approach B), *Use a Generic Attribute Table*, *Use Dual-Purpose Foreign Key*, *Create Multiple Columns*, *Clone Tables or Columns*, *Use FLOAT Data Type,* and *Assume You Must Use Files* the queries are based on the assumption that base tables, columns, or types have certain names. This could lead to both false-positive and false-negative results.

There could be false-positive results because developers can legitimately use a name that is associated with an antipattern in other context than specified in the antipattern. For instance, the result of the query of *Use a Generic Attribute Table* in a PostgreSQL™ 9.2 database refers to the tables *pg_class* and *pg_attribute* that are base tables in the system catalog. However, these tables do not have the design flaw described by the antipattern.

There could be false-negative results because the names in an actual database do not follow the naming conventions, which are the basis of the queries. There are many possible names. For instance, different authors suggest names like “object_type”, “entity_type”, “thing_class”, and “class” to the same base table of *Use a Generic Attribute Table*. Another example is that *One Size Fits All* refers to the column name *id*. However, one could instead use the names like *code* or *oid* and the design has the same problems as described in *One Size Fits All*. Finally, the names could be in different natural languages (current queries assume that the names are in English) and can be in singular or plural form.

The result of queries depends on the existence of a declarative constraint in case of *Always Depend on One*'*s Parent*, *One Size Fits All*, *Leave Out the Constraints* (approach B), *Use Dual-Purpose Foreign Key*, and *Specify Values in the Column Definition*. In this case missing constraints would cause false-negative results. For instance, in case of *Always Depend on One*'*s Parent* and *One Size Fits All,* the proposed queries cannot identify an occurrence of the antipattern if the corresponding foreign key or primary key constraint is missing, respectively. On the other hand, Blaha [3] reports reverse engineering results, according which only 10 % databases declared foreign keys and 75 % developers enforced primary keys.

The flaw detection procedure analyzes the existing data in the database (both inside and outside of the system catalog) in case of *Format Comma-Separated Lists* and *Assume You Must Use Files*. This could lead to both false-positive and false-negative results.

False positive results are possible because the procedure cannot determine what the data in the columns means to the users. For instance, in case of *Format Comma-Separated Lists*, the procedure cannot determine whether the separation characters are used to separate different attribute values or used, for instance, in the sentences of free-form text or source code statements. One could try to leave out columns that contain free-form text (like comments) or source code based on the names of columns. However, the results would not be reliable because of the reasons already covered in this section. On the other hand, the results could also reveal that lists of values or file paths are recorded as a part of free-form comments. In this case one could improve the database design by creating separate base tables/columns for recording this data. One could also search the occurrences of such antipatterns based on the declarative constraints, which are stated formally and determine the meaning of the data to the system. However, in this case there will be false-negative results if the constraints are missing.

False-negatives are possible because if there are no rows in the analyzed table, no values in the analyzed column, the data values are not expressive enough, or have different structure than is expected in the queries, then the result of analysis does not identify the problem. For instance, existing data values could contain exotic separator characters in case of *Format Comma-Separated Lists*. Another example is that a system could store all the files in the same folder (uses a fixed path) and hence records only file names and not full paths in case of *Assume You Must Use Files*.

There are additional reasons of false-positive results. A detected design fragment could resemble the design that is specified by an antipattern. However, semantically these designs are different and the antipattern does not apply in this case. The next example is based on *Leave out the constraints*. False-positives are possible in case of both proposed detection approaches. Let us assume that there are two base tables *Emp_wait_comp* and *Emp_on_vacation* in the database, both of which have exactly one column (EMPNO) with the same type. Their associated predicates, which describe intended interpretation, are “Employee EMPNO has requested a new computer” and “Employee EMPNO is currently on vacation”, respectively. Activities like being on vacation and requesting a new computer are independent of each other. Therefore, the number of an employee is either registered in both tables, is registered in one of the tables, or is not registered at all in the tables. There is no table for recording all the employees who currently work or have worked in the organization. The tables *Emp_wait_comp* and *Emp_on_vacation* do not participate in the foreign key constraints (approach A) but it is not an occurrence of the antipattern.

False-negative results can be caused by the logic of the detection approach. The queries of *Leave Out the Constraints* (approach B) and *Use Dual-Purpose Foreign Key* do not consider the possibility that a primary key and its corresponding foreign keys could be composite keys.

False-negatives can also be caused by the internal implementation-specific behavior of DBMSs. Some DBMSs may rewrite Boolean expressions of check constraints before recording them to the system catalog. For instance, PostgreSQL™ 9.2 replaces the Boolean expression of a check constraint *(sex IN ('M','F'))* with the expression *((sex = ANY (ARRAY ['M'::bpchar, 'F'::bpchar])))*, before recording it to the system catalog. If we create the search condition of a query of *Specify Values in the Column Definition* based on the first form of the check constraint, then the results will be incorrect in case of PostgreSQL™.

Finally, false-negatives can occur because of large number of database design options. The kind of constraint that is described in *Specify Values in the Column Definition* can be implemented in many ways in PostgreSQL™ 9.2. Firstly, the Boolean expression of the check constraint can be written in multiple different ways (for instance, *(sex = 'M' OR sex = 'F')*). One can implement the constraint by using an enumeration type that is not specified in the SQL standard

[22]. Hence, there are no views in the Information Schema [9] that would present information about this kind of implementation. Finally, it is possible that the constraint is implemented by using triggers, rules (an implementation-specific object type of PostgreSQL™), or even by the application programs. The queries cannot detect this kind of constraint implementations. In addition, the constraint could be implemented by using an assertion. However, our proposed query does not take it into account because to our knowledge currently no commercial SQL DBMS implements assertions.

Karwin [2] presents legitimate uses of antipatterns. Hence, it is possible that an occurrence of an antipattern does exist but after more thorough analysis by human experts it is decided that in this case one could use the design. It means that although we have detected the occurrence of an antipattern, we have not detected a design flaw.

All the information is extracted from the data about actual structure of the database instead of database design models. It might be the only way to find design flaws if the documentation of database has gaps, is inconsistent with the actual database, or is entirely missing. In some cases, we suggest the use of actual data values outside the system catalog. It would be impossible in case of model-based analysis. However, the result of the use of actual data values depends on the quality of data. For instance, if we try to use existing data values to identify missing constraints, then the results would be wrong if users have already registered data values that are inconsistent with the possible constraint.

The existing approaches that use querying of source code require specification of the metamodel of the corresponding software language and must parse the code to create a mapping between the metamodel elements and the elements in the analyzed source code. However, in case of querying the views of Information Schema, we do not need these steps because the metamodel is already specified by the structure of the system catalog and the mapping between the metamodel and database objects is established in the form of data in the system catalog.

Conclusions

In this paper, we analyzed 12 SQL database design antipatterns to find out whether one can search the occurrences of these patterns in the existing databases (and hence possible flaws in the database design) by querying views in the Information Schema and possibly base tables in other schemas. In case of one of the antipatterns it is impossible because the SQL standard does not specify indexes and corresponding Information Schema views. In case of other analyzed antipatterns one could use this kind of queries. However, false-positive and false-negative results are possible in case of the queries. We also analyzed the reasons of such results. The query statements are in the file:

http://staff.ttu.ee/~eessaar/files/Design_flaws_queries.pdf.

We do not claim that these are the only possible queries.

Future work should include case studies for analyzing existing databases by using the queries (including performance measurements of the queries). Another area of research is to find out whether one can also use similar queries for other tasks related to the source-code analysis.

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An Architecture for Mobile Context Services

Chad Williams and Jisna Mathew

Abstract
Determining the context of what a mobile user is doing currently, and in the near future is central to personalizing a user's experience to what is most relevant to them. Numerous methods and data sources have been used to try and garner this information such as GPS traces, social network data, and semantic information to name a few. In this paper we propose an architecture for combining various forms of data and processing into a service for providing a mobile user's context to applications. The goal of this work is to establish an architecture that can provide a more complete model of the information relevant to a mobile user and making this data available to interested applications.

Keywords
Mobile applications • Mobile personalization • Mobile architectures

Introduction

Personalization of web sites to user's preferences and current activity has become quite common, but providing this same type of personalization in mobile applications remains a challenge. There are many different sources and types of information currently being collected or inferred about travelers. Traditionally this information has primarily been categorized as either: travel context, describing trip characteristics; or user context, describing what the user is doing. Within this work, we use the term context to refer to the combination of these as well as additional information that further describes the situation and plans of the mobile user that might be relevant for personalization of mobile applications. Determining the current traveler context, and a more recent focus, predicting the context of a mobile user is a crucial step in being able to identify pertinent information for personalization based on a user's mobile context.

Numerous approaches to this problem have been used to attempt to infer various parts of this data. These techniques have included ways to either help directly with current activity context or indirectly as ways to better understand future context and thus future interests. Within this work, we examine the integration of each of these as part of a multi-pronged approach acknowledging that there are multiple components that can be used to improve a mobile user's context prediction. Each of the components proposed below addresses different aspects of the overall goal of learning the traveler context and activity patterns of an individual.

Based on the interrelated sources of data and the overall goals of these studies we assert that a consolidated service for providing individual mobile context to any registered mobile application is warranted. In this work, an architecture is proposed that establishes a general categorization of how activity patterns of an individual may be learned and predicted. The various components that are defined as part of this architecture and the benefits of addressing each of these areas is discussed as well as how they fit within the whole. This is followed by a discussion of future areas of research in the field and how the proposed framework supports these areas.

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_9,

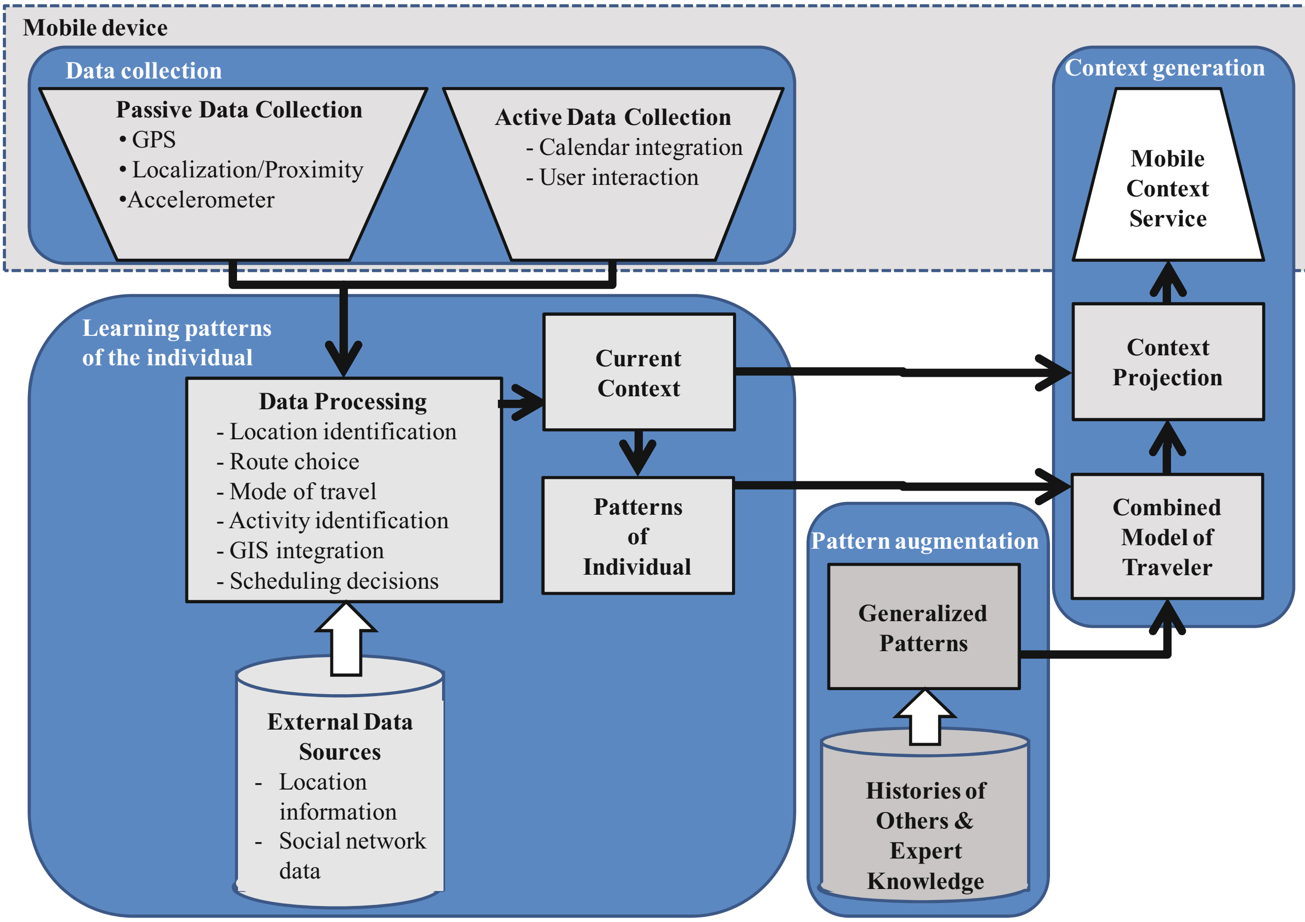

Fig. 1 Mobile context architecture

The purpose behind this architecture is to acknowledge that there are multitudes of ways systems can learn and determine the information necessary for personalization, but all of these techniques can be integrated in a common way. Learning the behavior of an individual is very complex when considering the number of spur of the moment decisions and patterns evolving over time whether slowly from changes in habit or abruptly from change in job. As a result, a single learning approach while it may suit one situation well may not be the best approach for other scenarios. Below an architecture is introduced that is intended to be flexible enough that multiple approaches to this complex task can explored while still fitting into the proposed framework.

Mobile Context Architecture

In developing an architecture for the task of individual activity pattern prediction, there were two primary goals. First, create a model that is flexible enough to not only capture the techniques discussed in this work, but also fit with approaches explored in the future as well. Second, the framework should be simple enough that it is easily understandable and approachable. By addressing these two goals the hope is that the architecture introduced here can be easily adopted by other researchers going forward.

The proposed architecture is shown in Fig. 1. The model is made up of four groupings of components organized by task: data collection, learning patterns of the individual, pattern augmentation, and context generation. The tasks of each of these groups are accomplished through a collection of components which are discussed in detail below. The data collection components are responsible for collecting all data from the user. The second group of components enhance the context through processing the data observed of the individual and incorporating knowledge from outside sources. The pattern augmentation component supplements individual patterns with those from outside sources to improve user pattern coverage. Finally, the results of the two previous groups are brought together combining individual and generalized patterns to project relevant context for the current situation as a service to interested mobile applications. The components related to this task, shown in white, include integrating the patterns of the individual and outside knowledge to produce a model of the individual traveler. The combined model of traveler's context can then be provided as a service for applications to create a more personalized experience for the user based on the information that is currently relevant to the user. A further description of these components is given below.

Data Collection

The first of these areas, data collection, is related to all forms of collecting data specific to the mobile user in question. It is made up of two components: passive data collection, and active data collection. These components together provide the tools for collecting observations of the user's activity so that they can be assembled into a model of the individual traveler. The combination of passive data collection plus data processing provide the implicit context of the traveler which can then be augmented or overridden by data that is actively collected from the individual. This combined view of the current context can then be used to help further refine the model of that individual traveler. All of these components can be integrated to form a fluid system for traveler data collection. However, as integration of these sources is not required a more in depth description of the traits of each of these components is given below.

Passive Data Collection

Passive data collection represents any source of information that can help provide data about the user's current context or future plans that don't require interaction with the user. The general requirement of these sources is that the data can be obtained unobtrusively such as the user carrying a device with them. Primarily the use of these sensors have fallen in two groups: location detection; and environment sensing.

From a mobile perspective, sensors for location detection are the key to determining perhaps the most pertinent form of context namely is the user traveling or at a location. The benefits of GPS data collection has been a central theme throughout much of the research in this area, but other sources may also provide useful information. One example of this is the use of Wi-Fi networks to identify a good approximation of someone's location indoors based on signal strength [1].

In addition to sensors that observe location, there are a number of other passive sources that might also help establish an individual's context through sensing environmental characteristics. The most commonly used of these has been the accelerometer for trying to determine context based on activity likely associated with the perceived movement. Other examples have included the use of RFIDs for detecting the objects being used [2]. Still other approaches have used sensors of ambient light and sound to help detect the type of environment the person is in [3].

Active Data Collection

The second component of data collection is active data collection. The purpose of this component is to collect data that might help establish the context that cannot be determined from available passive sources. Like the various types of passive sources, this component is not required, but having some sort of interaction can help capture data that would likely not be captured by passive sources alone. The main drawback of active collection is it directly impacts the effort required of the individual to get benefit out of the service. Thus the goal would be active collection would take more of an optional role; whereby if the data is provided it helps, but is not required to make the application function. By having the input be optional, the result is a data set that may have missing data from when a user either opts not to provide detail or was not prompted to reduce their burden. Being able to utilize when input is provided, or even learning if there is meaning behind when it is not provided, could help further enhance the application's understanding of user constraints and preferences which are unlikely to be obtained through passive means alone.

One example of this would be integration with a user's calendar which they already use to keep track of various events and/or meetings. Integrating this data with other sources could allow activities observed to be tied to calendar events for even more detail. This is one example of a source that requires active input by the user, but because much of the data would likely be entered with or without context integration; it comes with little cost in terms of user burden. However, in other applications additional user interaction may be worth the additional cost.

Another approach is more direct interaction. While this interaction may be as simple as always allowing the user to enter more detail, more sophisticated techniques have been explored that use knowledge of the current context to determine the active data collection needs. One form of active collection discussed in Auld et al. is prompting the individual for planning information or activity information only when the information cannot be determined from passive sources alone [11]. Other studies have taken different approaches. Liao et al.'s application "Opportunity Knocks" observed travel patterns and would prompt user's when they deviated from the known patterns if that was their intention, to help cognitively-impaired people use public transit safely [4]. As can be seen by applications such as these, while any of these questions could be asked at any point by using the current context, intelligence can be incorporated such that questions are only asked when certain conditions are met as a way of reducing the burden on the individual. Through interactions such as these it is easy to see how occasional interactions with the user might significantly help set the context of the user beyond what can be collected without their interaction.

Learning Patterns of the Individual

Data Processing

The data processing component is responsible for taking the various forms of collected data and synthesizing it into a form that can be used to help provide the individual's context. Many studies have examined the ways GPS data can be processed as it is collected to identify significant locations, returns to locations of interest, and start and stop of travel. These are just a few of the ways passive sources can be processed to provide context. Techniques are being explored for processing GPS logs for transportation mode detection and locations of change of mode as well [5]. Other work has focused on future end-to-end route prediction based the individual's history and recent GPS trace [6]. Work in ubiquitous computing has examined activity identification as a function of visiting known locations [7]. One could imagine a similar approach being used matching up an individual's current position with detailed geographic information system (GIS) maps to determine the activity on a larger scale.

In addition to these direct approaches to processing the current location information, other approaches have been used that combine location information with other sources such as calendars. By integrating these different types of passive sources such as the user's calendar and when various events were entered or rescheduled, combined with the GPS information it can provide additional context of whether the current activity was scheduled or whether the current activity implies rescheduling other activities [8]. Thus while the data processing component may take many different forms, the overall goal of these different methods is to enhance the raw passively collected information into a detailed description of the individual's current context.

External Data Sources

One of the ways that real value can be added to a mobile user's context is enhancing their personal information with data from outside sources. One of the most well known examples of this is incorporating traffic data based on a user's route information; however there are many other opportunities here as well. An example of this is using location information lookup to determine the likely activity the user is currently doing [13]. One of the more recent areas, which has the potential of significantly changing the information known about events and the people involved, is combining the information about the detected situation with data from the user's social networks [14]. In addition to these, the amount and variety of types of information available that may help in determining what is relevant to the mobile user stands to serve a major role in a context architecture.

Current Context

The component referred to as current context represents the synthesis of all information either through data processing related to passive and active sources into a single view of what is currently observed about the individual. This snapshot of the context of the individual serves two roles. First the current context can be used to help further build a model of that traveler's individual history or patterns. Second, the current context can be fed into a prediction model to tailor the context forecast based on the current knowledge of the state of the system.

Works such as those by Hinze and Junmanee, and Vanajakshi et al. have shown significant benefit in expanding content to include data such as time availability, real-time weather, traffic updates and events such as accident [15, 16]. Also factors like financial situation and the group of people traveling along with the mobile user have been shown to impact the individual's real-time travel decision making [17].

Patterns of Individual

The patterns of the individual represent the historic patterns specific to that individual. This history can take many different forms including movement patterns, activity patterns, and scheduling behavior to name a few.

When considering the many aspects of the mobile user's context, their history can be thought of as a sequence of sets of context information. Being able to predict the progression of this set sequence is a key aspect to more sophisticated personalization. As a result, another area emerging for future research is scheduling patterns of an individual or how the individual plans specific tasks and make adjustments to their schedule as conflicts arise. The combination of these varying types of history or patterns collected on the individual represent the sum of the knowledge that is specific to that individual.

Pattern Augmentation

One of the challenges in learning the behavior of an individual is that it can take a long time before all intricacies of their behavior have been observed. A similar problem occurs frequently when a system first starts to learn the patterns of something with very little history, referred to as the cold start problem. One of the ways this can be addressed is by incorporating common patterns outside of the history of the individual to jump start the learning process until more observations are made. Within the proposed architecture this process is split into two components: histories of others and expert knowledge; and generalized patterns.

Histories of Others and Expert Knowledge

The various sources of outside patterns that might be incorporated into the learning or modeling process of the activity patterns of the individual are represented by the histories of others and expert knowledge component. Traditionally the sources used for helping identify typical patterns are derived from either the history observed in other users or expert knowledge. An important aspect to consider about these sources is while they may be in an identical format as the patterns recorded for the individual being modeled, this does not have to be the case. Similar patterns can be drawn from histories in the same format, but it is also possible for outside sources to be very different in their raw form. This component represents not only the various sources of the patterns but also any transformation necessary for the sources to be meaningfully incorporated into the learning process.

Recent work has shown that the pattern base can be further expanded beyond just the immediate area. Work by Williams et al. has shown that patterns recorded in even different cities entirely can be used to help aid in rapidly producing a meaningful model of the traveler until a larger base of training examples can be collected [12]. By mapping the underlying meta data to a set of common concepts, the source of these histories can vary dramatically in terms of differences in location and transit networks yet the underlying traveler patterns remain similar.

This component also may represent other ways histories may be beneficial in learning about the patterns of the individual. Ashbrook and Starner demonstrated that this basic idea could be used within similar groups of people to label significant locations, which would be one way of learning the activity patterns of someone without them specifically entering information about a place [9]. Perhaps the most common forms of this is traffic conditions where the anticipated travel for a user does not have to rely on that user's history alone but the travel times of others can help predict the expected travel time of the individual in question.

In addition to using observations of others as a way to quickly form a basis of typical patterns, another source for these patterns can be in the form of expert knowledge. An example of this would be estimating public transit times. Given the extensive number of public transit routes within a large city, even with a large set of similar histories in the area of the person it would be possible to not have complete coverage of the network. One way of addressing this problem would be to use knowledge of the transit agency to populate the data on the public transit network and schedules. As these various examples demonstrate the use of the histories of others and expert knowledge can serve a critical role in augmenting the history collected specific to the individual.

Generalized Patterns

Once outside sources have been identified and transformed into a form that is meaningful for expanding on the patterns of the individual, there may need to be some additional form of processing needed. The generalized patterns component represents any processing necessary to allow these various sources to form generalized patterns that can be used in the absence of data specific to the traveler. Together these patterns can form a collection of typical patterns that can be drawn from in order to model patterns beyond that observed in a limited history of the specific traveler we are interested in.

Developing activity and scheduling models of travelers based on generalize patterns has been a focus of much transportation planning research, but is only now being examined for the purpose of individual traveler modeling. These models rather than just examining the trips made use a more behavioral approach to determine the reason trips are made and how they are scheduled. Bowman and Ben-Akiva's work demonstrated that these types of models could be used for future activity scheduling in addition to next trip prediction [18]. Since this study, the interest in this type of reason based multi-trip activity modeling has greatly increased as a potential alternative to modeling next trip destination and activity alone.

Other work Kitamura et al. in this area has examined how shifts in the timing of routine activities can impact the scheduling of other activities resulting in a ripple effect of disruption and associated rescheduling behavior [19]. These findings are promising for providing meaningful predictions when a person deviates from their routine. While deviations from known patterns of the individual currently pose problems for predicting context, using generalized patterns may aid in predicting the underlying activity at unknown locations. While a location may not be constant, the proximity of the location of an activity pattern is relatively stable meaning different attributes of the predicted next activity are also likely to be useful.

Context Generation

Once the patterns of the individual and any outside patterns have been collected, the task then becomes integrating these different views (if both are used) to complete the current traveler context and project future context. The following architecture components are proposed for represent this process: model of the individual traveler; activity pattern prediction; and traveler context service. A description of each of these components is given below.

Combined Model of Traveler

The combined model of the traveler component represents how the combination of individual patterns and generic patterns can together create a consolidated model of a person. The motivating factor behind this combining step is the need to augment individual histories. While using the patterns of the individual alone will provide a highly customized model it also is greatly limiting in terms of the number of available options observed as well as a more limited history. From the options perspective, if only the user's individual history was used, recommendations could only be based on what that user has previously done. By combining the individual patterns with those of similar users a much wider range of potential options can be discovered as well as increasing a training base when only a limited history of the individual is available.

The other aspect that can be gained from this is being able to infer metadata. For example being able to determine the flexibility of planning an activity such as likely timing and distance constraints is something that often is not observed about a user, but by using the planning patterns of others this type of information can sometimes be inferred [12]. By using a combination of individual and general patterns a model can be created that more rapidly produces meaningful predictions than using the patterns of the individual alone.

Context Projection

The traveler context projection component is responsible for taking the combination of the current context and the combined model of the traveler to project information that is likely relevant in the future. This may take the form of inferring additional information about the activity taking place, such as how flexible the duration of the activity; or be relevant to the likely next thing(s) the user is going to be doing. Some examples of this projection could be route related, activity related, or relevant to planning. The task of the context projection component is to integrate these projections into the context such that applications using the mobile context service can determine what is relevant not just regarding what the user is currently doing, but also what is useful based on what they likely will be doing or planning. Thus, this component is simple enough to describe the process of predicting elements of current context as well future contexts while still being flexible enough to include behavioral information as well as physical travel details.

Mobile Context Service

The mobile context service is intended to provide an interface to any mobile application for retrieving the context information that is relevant to personalization. Presently the majority of personalization, if it is done at all, is limited to the information gathered by that particular application. This approach has two significant drawbacks. First, it means each application that wishes to collect sensor data for personalization needs to be given access to a wide range of sensors which could be more than users are willing to share. Second, the processing might be duplicated when most likely some parts of the context information could be reused across multiple applications if it was provided as a service.

The goal of the proposed context service is to eliminate this duplication and have the architecture be responsible for determining the context and make it available to all applications the user gives the necessary permissions. This service can then be used to personalize the user experience based on what context is most useful to a particular application given their immediate situation as well as looking forward.

To create a more beneficial personalization experience, the purpose of the component represented by this service is to provide a combination of not just movement projection but the behavioral activity pattern context as well. Essentially this component provides this broader context in completing the current context as well as projections of future contexts. By addressing this larger picture of the likely future behavior and associated constraints, this service could provide a wider range of information that could be useful for personalizing mobile applications.

Discussion

Across all of the studies described above, the goal has been to model information about what the traveler is doing or going to be doing. We propose that the end goal of a mobile context service is to build a model such as the one described above that contains more than just want the user is currently doing. In essence, having a combined model that captures information such as a detailed model of the traveler's current context and their projected future context including their scheduling/rescheduling behavior can provide a rich model for customized personalization. Many studies have focused on developing portions of this model, but combining all of these sources of information for a more complete model of the traveler is still an open area of research. Likewise the capabilities of personalizing applications based on the integration of not just what they are doing, but what they will be doing has only begun to be touched upon and represents a strong area for future research. Some of the early work in this area, like that by Amini et al., is beginning to look at using projected locations to enhance mobile search [10]. Also, while some studies have already begun to look at this, one of the more challenging and open problems in this area is understanding the reasons behind the decisions travelers are making. While a rich model of what the traveler is doing provides a view that can be used for personalization; understanding when decisions are made and what influences them presents an even greater opportunity to make a more personally relevant experience.

As described above the proposed conceptual framework represents a consolidated way of addressing the various components of individual activity patterns and the associated traveler context. Although this framework has been examined with respect to the ongoing research in each of these areas, the conceptual integration of these components is flexible enough that the hope is that it will provide a standard architecture for future studies in this area as well. In describing this framework the focus has been on explaining how each of these different components can fit together to address the larger goal of traveler context projection, however it is important to note that solutions could just address portions of this overall framework without impacting the representative value of the architecture. For example, models discussed earlier that use individual history alone would not include the components related to incorporating the histories of others or expert patterns while the remainder of the framework would still describe the work. Likewise, models of generalized behavior to simulate the activity patterns of individuals would also fit this overall framework just without the incorporation of individual patterns. As a result, we propose that the framework introduced here could form a basis for constructing traveler context prediction going forward.

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An Actuated Tail Increases Rapid Acceleration Manoeuvres in Quadruped Robots

Amir Patel and M. Braae

Abstract

The cheetah (*Acinonyx jubatus*) is arguably one of the most manoeuvrable terrestrial animals. For future time-critical missions, legged robots will need to possess capabilities similar to the cheetah. In this paper, a rapid acceleration quadruped system is designed and is found to be limited in manoeuvrability. However, we show that by the addition of an actuated tail, a considerable increase in stride-averaged acceleration is obtained.

Keywords

Quadruped robots • Manoeuvres • Acceleration • Terrestrial animals

Introduction

Manoeuverability is paramount to survival in nature. Agile manoeuvres such as rapid acceleration, abrupt stops, running jumps and near-instantaneous turns seem effortless to animals [1, 2]. Thus, for future legged robots to perform time critical missions in dynamic environments, it is clear that we should look to nature for inspiration.

Manoeuverability, from the biomechanics literature, can be defined as an animal's ability to change its velocity for a specific purpose [3, 4]. However, as stated by Alexander [1], the biomechanics study of manoeuverability has been fairly limited, with the majority of research concentrating on steady state locomotion such as galloping and trotting [5]. This can be attributed to the complex dynamics these transients comprise.

Nevertheless, some outstanding contributions have been made in this regard for terrestrial animals. The Pitch Avoidance Model [6] developed by Williams et al. essentially determined a limit to (de)acceleration of quadrupeds to avoid pitch instability. In this paper, the authors have shown that under low velocities, quadrupeds (horses & dogs) are not limited by muscle power but instead by their tendency to avoid pitching up. This is similar to "popping a wheely" for motorcycles. Additionally, other studies have focused on manoeuverability in dogs and specifically in greyhounds [7–9, 5], goats [10], horses [11, 12] and ostriches [13].

Legged robot agility and manoeuvrability has also not received much attention, as discussed by Bowling [14]. Bounding, trotting, turning and galloping quadruped robots have been successfully designed [15–18]. As a control systems analogy, one can say that the research has focused on *steady state* behaviour, as opposed to *transient* behaviour. Indeed, a high speed quadruped robot has been designed by Boston Dynamics [19], capable of reaching over 12 m/s (and in so, breaking the land robot speed record). But here again, the focus is reaching a top speed and not explicitly manoeuverability.

The inspiration for our research arose from videos and images of the cheetah (*Acinonyx jubatus*) from National Geographic [20]. Here it was observed that, during acceleration manoeuvres, the cheetah would swing its tail downwards as can be seen in Fig. 1. This curiosity was further ratified by recent interest in the robotics community demonstrating the use of tails for attitude control [21–23]. Kohut et al. [23] were the only group to look at rapid turning (albeit at low speeds) by employing the tail.

More recently, a Cheetah-inspired tail study has been presented by Briggs et al. [24] which illustrated promising results. Their research (still in the fledgling stages) has produced the following outcomes:

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_10,

Fig. 1 Cheetah rapidly accelerating while swinging its tail downwards. Image courtesy of National Geographic [20]

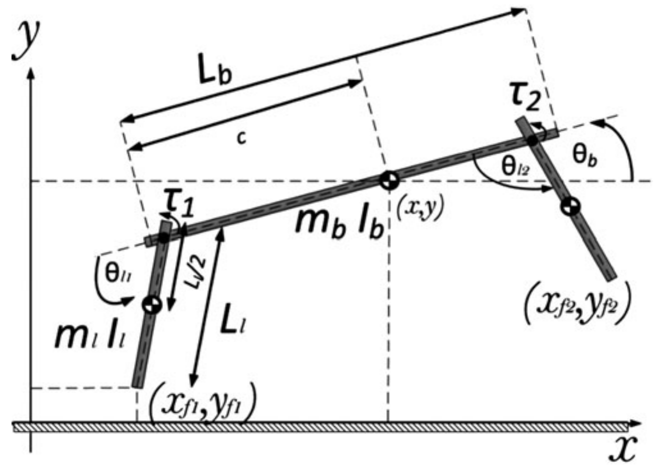

Fig. 2 Schematic of the quadruped model

- a tail can provide greater average torque than a reaction wheel for short times of interest;
- a 2 DOF tail controller can be designed for free space attitude control; and
- a tail can effectively stabilize a robot (at standstill) experiencing a large force disturbance.

These results, and the aforementioned studies on tails, have still not looked at how a tail can be utilized to increase the manoeuvrability. Furthermore, these designs have all assumed that the systems are closed, and momentum is thus conserved.

In what follows, this paper will address the issues of manoeuvrability for quadrupeds. Firstly, in section "Rapid Acceleration Manoeuvres", the paper begins by developing a mathematical model for a quadruped (sans-tail) and subsequently designing a controller to command a velocity (per stride). It is shown that there is indeed a limit to the average acceleration produced per stride. Following this, in section "Introducing the Tail", the quadruped model is augmented by the addition of a tail. A simple tail controller is then designed, regulating body pitch rate. Here it is shown that, by the addition of an actuated tail, the quadruped is able to generate a much greater acceleration per stride. These results are then discussed in section "Discussion". Finally, conclusions are drawn and recommendations for future work are made in section "Conclusion".

Rapid Acceleration Manoeuvres

This section entails the analysis and design of the controller for rapid acceleration of a quadruped. The goal of this controller will be to obtain the highest stride averaged acceleration without pitch angle instability.

Mathematical Model: Quadruped Without Tail

The quadruped system is modelled as three thin rigid links as shown by Fig. 2 comprising two identical legs and a body. Each leg is activated by an ideal torque actuator.

The reader should note that even though the system is only modelled in the sagittal plane, this is sufficient to represent rapid acceleration as the bounding gait was observed by [5] and [8] during maximal acceleration manoeuvres. Furthermore, as is shown by [5], the foreleg does not contribute to maximal movement initiation (from standstill) and consequently, will be considered to be off the ground.

Phase Transitions

The quadruped model is a hybrid system containing both discrete and continuous dynamics [25]. A transition map is shown by Fig. 3.

These phases are described below:

a) *Hind Leg Stance:* This is the starting point of the simulation. The hind leg is on the ground, while the foreleg is in the air. This is aligned with the results obtained in [5]. It is assumed that sufficient friction is available to avoid slipping and the ground does not deform. To transition to the next phase, the ground reaction force (λ_y) must fall below zero.
b) *Flight:* In this phase, the system is under no constraints and is purely ballistic. We have also assumed here that aerodynamic effects can be neglected. The transition to the next phase occurs when the y-position of the foot becomes zero.
c) *Foreleg Stance:* This is the final stage of the movement and the simulation is stopped here.

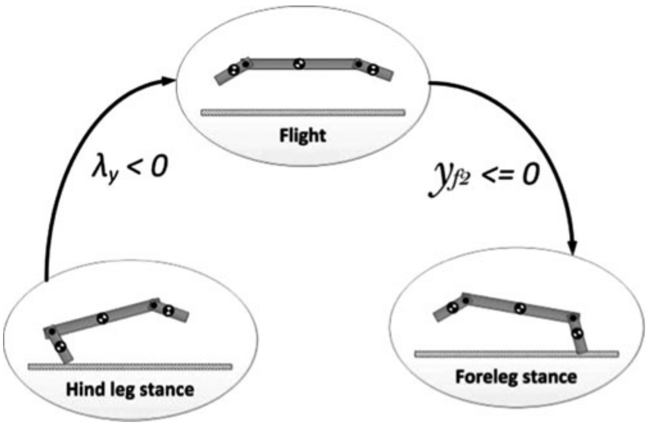

Fig. 3 Transition map showing the three phases of the dynamic model

Continuous Dynamics

The quadruped dynamics are obtained by using the Euler-Lagrange Method described in [26, 27] and are formulated in the familiar form[1]:

$$\boldsymbol{M}(\boldsymbol{q})\ddot{\boldsymbol{q}} + \boldsymbol{C}(\boldsymbol{q}, \dot{\boldsymbol{q}})\dot{\boldsymbol{q}} + \boldsymbol{G}(\boldsymbol{q}) = \boldsymbol{B}\boldsymbol{\tau} + \boldsymbol{A}\boldsymbol{\lambda} \tag{1}$$

where, the generalized coordinate vector is given by:

$$\boldsymbol{q} = [x \quad y \quad \theta_b \quad \theta_{l1} \quad \theta_{l2}]^T \tag{2}$$

Where the symbols for these and all others are graphically shown in Fig. 2.

During the hind leg stance phase, the x and y coordinates are constrained. These constraint forces, $\left(\boldsymbol{\lambda} = [\lambda_x \quad \lambda_y]^T\right)$ are calculated as per the Lagrange Multiplier method described by Murray [27]. The constraint Jacobian, $\boldsymbol{A}$, is calculated by using the following constraints:

$$x - c\ \cos\theta_b - L_l \cos(\theta_b + \theta_{l1}) = 0 \tag{3}$$

$$y - c\ \sin\theta_b - L_l\ \sin(\theta_b + \theta_{l1}) = 0 \tag{4}$$

The dynamics given by (1) are valid throughout all the phases. However, during the flight phase, the constraint force vector, $\boldsymbol{\lambda}$, is set to zero.

Now, the dynamic equations have been provided, the next section deals with the rapid acceleration controller.

Controller Design

The goal of the control system is to obtain the highest velocity at the end of the stride. In other words, we desire the maximum stride averaged acceleration $(\overline{a}_{stride})$.

[1] For the sake of brevity, the $\boldsymbol{M}$, $\boldsymbol{B}$, $\boldsymbol{C}$ and $\boldsymbol{G}$ matrices have not been shown as their derivation is fairly trivial.

For the sake of simplicity, only the hind leg torque will be used to control the acceleration. In fact, during the stance phase, the foreleg is commanded to keep it's initial leg angle constant.

Acceleration Control

This controller will employ the torque actuation about the legs to accelerate the quadruped body forward. Unfortunately, having only two torque inputs and five states signifies that we have an underactuated nonlinear system. This implies that we cannot perform full state feedback linearization [28]. However, we can perform Partial Feedback Linearization (PFL) as described in [29] to linearise the desired state.

Firstly, we note that in the hind leg stance phase, the x and y coordinates are constrained, and can thus be ignored. So, we actually have a reduced three state system with the generalised coordinates:

$$\boldsymbol{q}_{reduced} = [\theta_b \quad \theta_{l1} \quad \theta_{l2}]^T \tag{5}$$

We can now write the output equation as,

$$x = c\ \cos\theta_b + L_l \cos(\theta_b + \theta_{l1}) \tag{6}$$

which is the Cartesian x position.

Differentiating (6) twice we obtain an expression for the acceleration that we would like to maximise per stride. Now, following the method described in [29], we can then set this acceleration to be some variable which can command. This is shown as,

$$\ddot{x} = v, \tag{7}$$

which implies we now have a linear system.

A simple PI Controller is selected to control the output variable, $\tilde{x}$. This controller will command a ν, which will then be converted to a corresponding hip torque (τ_1) by some nonlinear mapping as described in [29] and is graphically illustrated below in Fig. 4.

Velocity Control

To command a velocity for the stride, a velocity controller is developed. This is based on the simple proportional controller that is employed to command a relevant acceleration to the acceleration controller.

Phases and Controllers

Once the quadruped enters the flight phase the aforementioned controllers are disengaged. This is due to the fact that the hind leg is not in contact with the ground, and is hence, unable to propel the body forward.

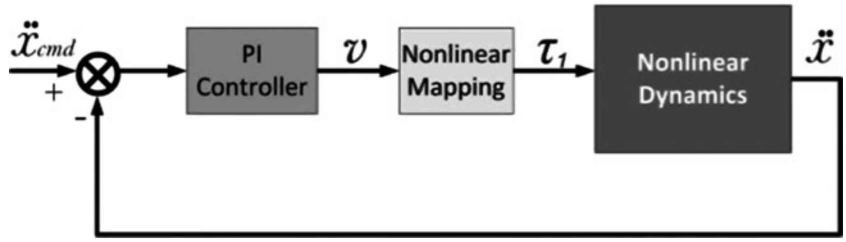

Fig. 4 Acceleration controller architecture

In the flight phase, the hind leg is regulated to keep its leg angle constant by means of another PFL controller. The same goes for the foreleg. However, when the y acceleration falls below zero, the foreleg will be commanded to an angle of $\frac{\pi}{2}$. This will enable the leg to land appropriately for the foreleg stance phase.

Simulation

The rapid manoeuvre was tested in simulation by implementing the quadruped dynamics (1) as well as all the controllers in Simulink. The initial conditions ensure that the quadruped is in the "set" position described by [5].

As described before, we desire the highest stride averaged acceleration, hence this performance metric will be calculated as follows:

$$\overline{a}_{stride} = \frac{v_{end}}{t_{stride}} \tag{8}$$

where, v_{end} is the velocity at the end of the stride and t_{stride} is the stride time (the length of time of the hind leg stance phase).

The quadruped model parameters are shown in Table 1.

Table 1 Parameters of the quadruped model

Parameter	Value	Units
Body mass (m_b)	10	kg
Body moment inertia (I_b)	0.858	kg m^2
Hip-to-COM length (c)	0.55	m
Body length (L_b)	1	m
Leg mass (m_l)	1	kg
Leg moment inertia (I_l)	0.0208	kg m^2
Leg length (L_l)	0.5	m

Simulation Results

The system was simulated and given velocity step commands. The data obtained for a 2.5 m/s step command is shown in Fig. 5 and snapshots of the animation are illustrated in Fig. 6. It is evident from the plots below that the control system architecture can effectively command a velocity per stride without toppling over. In fact a stride averaged acceleration of 7.11 m/s^2 is obtained.

However, when we command a velocity of 3 m/s the quadruped flips up and the forelegs are unable to land adequately to begin the next stance phase. The body pitch angle is illustrated in Fig. 7.

Figure 7 illustrates that when the velocity command is too great, the quadruped experiences a significant body pitch rate. This is shown by rapidly increasing the body pitch angle. Thus, although we can effectively command a velocity in the stride period, we are indeed limited by the Pitch then Power model [6] mentioned in the introduction. Attempting larger velocity commands results in the quadruped not landing on the foreleg appropriately.

In the forthcoming section, we will show that by the addition of a tail, we can dampen out this pitch rate and accordingly command a larger velocity and ultimately, a larger stride averaged acceleration.

Introducing the Tail

With inspiration from the cheetah we will now introduce a tail mechanism to our quadruped. We will subsequently employ this tail in a swinging down motion when rapidly accelerating with the optimism that it will gain us more manoeuvrability.

Mathematical Model: Quadruped with a Tail

A simplified system model is developed to emulate an actuated tail on a quadruped robot. A graphical representation is depicted below in Fig. 8. For the sake of simplicity, we have idealised the tail as a point mass attached to a massless rod as done by [21, 23]. This tail is attached to some torque actuator,τ_3, capable of swinging the tail.

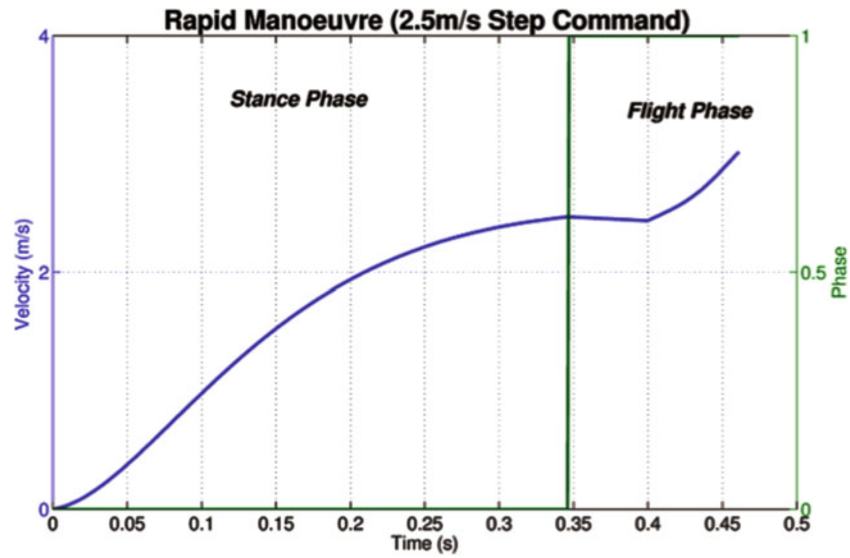

Fig. 5 Velocity response to a 2.5 m/s step command

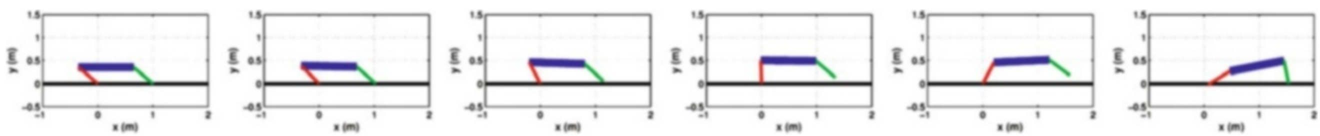

Fig. 6 Snapshots of the quadruped performing a rapid acceleration manoeuvre

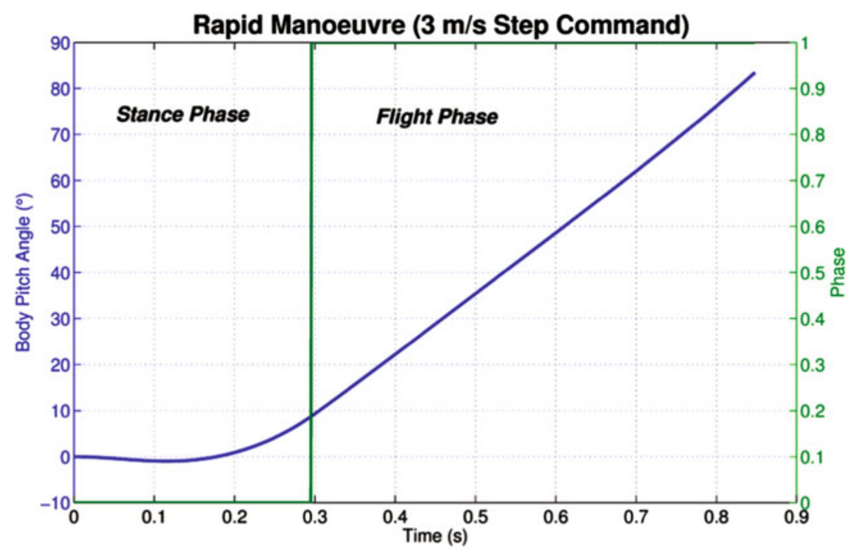

Fig. 7 Body pitch angle response to 3 m/s velocity input. Here, the quadruped flips up and the forelegs are unable to land on the ground

As in section "Rapid Acceleration Manoeuvres", the dynamics are derived using the Euler Lagrange Method. The generalized coordinates are now:

$$\boldsymbol{q} = [x \quad y \quad \theta_b \quad \theta_{l1} \quad \theta_{l2} \quad \theta_t]^T \tag{9}$$

Where θ_t is the relative angle between the body and the tail. Furthermore, the constraints are calculated as discussed previously.

Now that the revised dynamics have been defined, the next step is to design the controllers for the tail.

Controller Design

To ensure a fair comparison, the acceleration and velocity controllers designed in section "Rapid Acceleration Manoeuvres", will be kept the same. Thus, the only task to perform is to design the tail controller.

As illustrated in section "Rapid Acceleration Manoeuvres", an increased velocity command results in a large pitch rate, which ultimately flips the quadruped up. Therefore, the tail controller will command the tail to counteract or dampen the pitch rate.

Again, we follow a PFL approach, as described in section "Rapid Acceleration Manoeuvres". Our output will now be the body angle (θ_b). Then, by differentiating twice, we set the second derivative of the output as:

$$\ddot{\theta}_b = \mu, \tag{10}$$

which has now become a linear system.

Remembering that we would like to control the body pitch rate, we obtain the following (in the Laplace domain):

$$\dot{\theta}_b = \int \mu dt, \tag{11}$$

The reader will note that the dynamics are now simply that of an integrator with some gain. By selecting an appropriate proportional feedback (K), we can position the error dynamics as we desire.

Finally, we would also like the tail not to counteract any negative pitch rates as these are part of the motion of the bound. We thus add a saturation and in doing so, clip the error signal appropriately. The complete tail control system is shown below in Fig. 9.

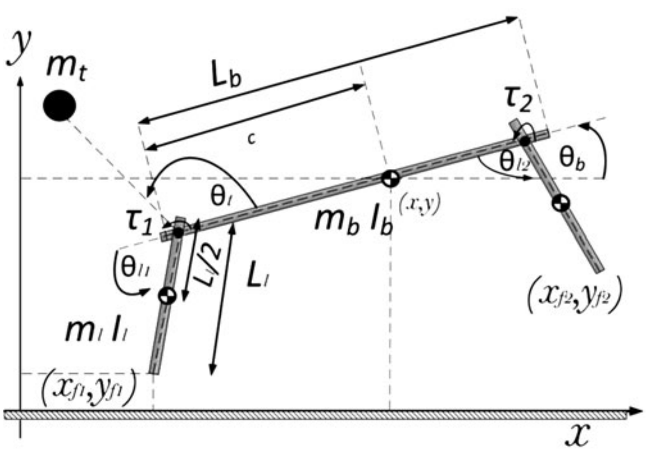

Fig. 8 Schematic of the quadruped model with a tail

Simulation

The quadruped with tail is now tested in simulation in Simulink as in section "Rapid Acceleration Manoeuvres". The model parameters are identical to those in Table 1 with the addition of:

- Tail Mass (m_t) = 1 kg
- Tail Length (L_t) = 0.8 m

Furthermore, the initial condition of the tail is set to 90° to allow for sufficient stroke.

Simulation Results

As in the previous section, the dynamics are simulated in Simulink. The quadruped was given a velocity step command of 3.5 m/s and the resulting response is shown in Fig. 10 and snapshots of the simulation are shown in Fig. 11.

It is clear that the system is now capable of accelerating more rapidly while still landing adequately on the foreleg. In fact, as is shown by Fig. 10, the system obtains a stride averaged acceleration of 11.91 m/s^2. Larger velocity step commands were attempted, but these resulted in the tail striking the ground.

Discussion

In section "Rapid Acceleration Manoeuvres", a set of controllers was developed to generate rapid acceleration manoeuvres. The velocity controller was capable of sufficiently commanding a velocity in the stride. However, when the commanded velocity was too high (>2.5 m/s), the quadruped would flip.

The explanation for this is that the robot enters the flight phase with a significant positive pitch rate. This pitch rate can

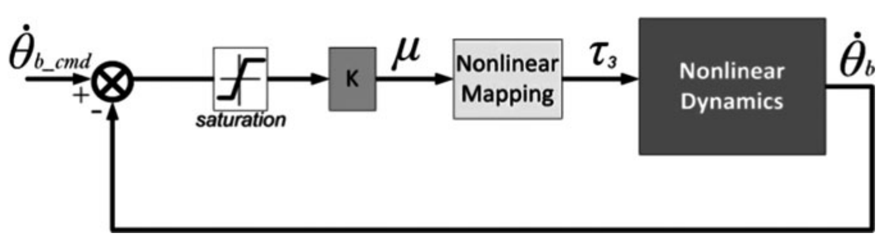

Fig. 9 Tail controller architecture

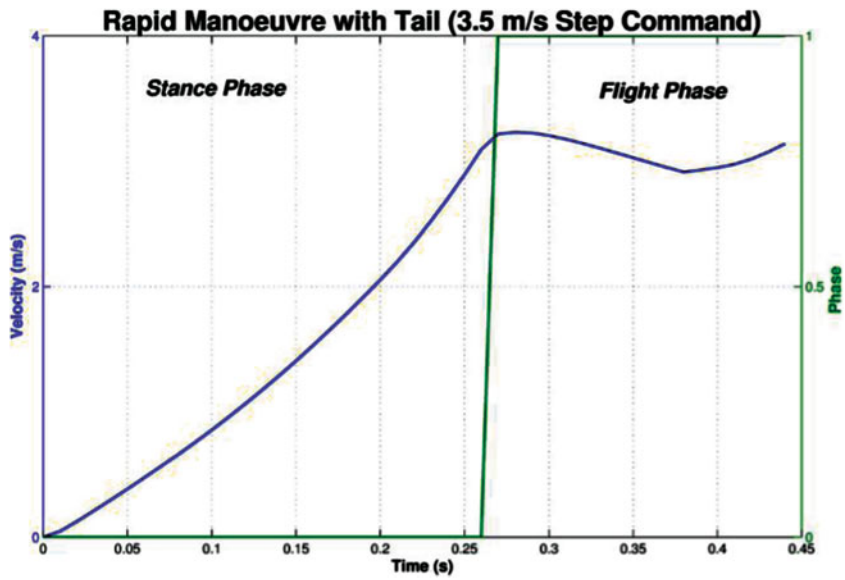

Fig. 10 Velocity step response to 3.5 m/s command. Evidently, the tail allows the quadruped to perform more rapid manoeuvres

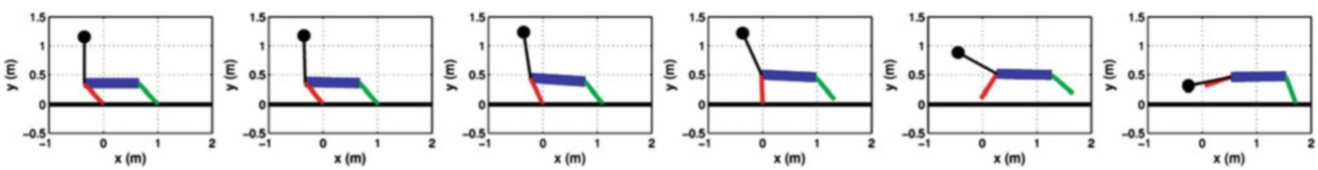

Fig. 11 Snapshots of the quadruped with a tail performing a rapid manoeuvre. The reader should note the sympathetic swinging action of tail

be attributed to the net ground reaction force vector not passing through the centre of mass, resulting in a moment. This behaviour was also observed in horses and greyhounds [6].

Subsequently, a tail was added to the quadruped model. This tail was then employed by a control loop to counteract the pitch rate experienced during the rapid acceleration. Although the pitch rate controller was a simple proportional controller, a substantial increase of stride averaged acceleration was observed. This is because:

- The pitch rate was damped and thus, a greater velocity could be commanded
- The stride time was reduced

Furthermore, it was observed that by increasing the commanded stride velocity even further, the tail would not have sufficient stroke and would hit the ground. One solution to this problem would be increasing the length or mass of the tail. The reader should note that the quadruped model and controllers have deliberately been made simple to illustrate the potential that tails have for manoeuvrable legged robots.

Conclusion

This study investigated manoeuvrability in quadruped robots, with a key focus on rapid acceleration ability.

The first section introduced the topic and emphasized the topic of manoeuvrability from a biomechanics perspective as well as that from the robotics fraternity. Additionally, the topic of employing tails as inertial actuators was also mentioned.

Subsequently, a simple model of a quadruped model was created to simulate the rapid manoeuvre. Based on this, simple acceleration and velocity controllers were developed. It was shown that these controllers are capable of rapid manoeuvres, but are limited to toppling the quadruped due to increase pitch rate.

With inspiration from the cheetah, a tail was added to the quadruped. It was hypothesized that swinging the tail could counteract the excess pitch rate induced by rapid acceleration. A simple proportional controller was designed using the tail as an actuator. This system resulted in a significant increase (~70 %) in stride averaged acceleration over the system without a tail.

Future work will include investigation of more complex controllers for the tail actuator such as Sliding Mode Control [30] or Optimal Control [31]. Also, rapid turning at high speed as well as deceleration should be investigated.

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PlantsVN: An User-Friendly Software for Creating and Managing Personal Plant Database and for Plant Family Identification

Nguyen Van Sinh

Abstract

PlantsVN is a software that combines the plant database functions with the utility of family identification of plant specimen. PlantsVN allows users to create and manage personal plant database and identify plant specimen. Apart from the software accompanied key, the users can easily create own keys using the key file child window. The result of the identification is documented by displaying all the taxa of the plant database matched with the characters of the plant specimen.

This paper describes the technique of integrating the plant identification utility into the plant database software that has been used in PlantsVN-software. The paper also document on the functionality of the PlantsVN-software that is free available at the website of the Institute of Ecology and Biological Resources, Vietnam Academy of Science and Technology (http://iebr.ac.vn/pages/1PlantsVN.asp).

Keywords

User-Friendly software • Personal plant database • Plant family identification

Introduction

There is a wide range of plant databases. A plant database can be large and include plants of a region [7], or of a whole country [12]. But a plant database can also be created for an arboretum [6]. The plant databases are useful not only for management of plant resources of various types but also for research and education, as the browsing through a plant database give us much information.

There are also many softwares for plant identification, but not all of them are dedicated to work with a database. An example is the internet based system for world wide flowering plant family identification developed by Ray Phillips at Colby College [8]. Following are the two softwares that can be embedded to a plant database.

The INTKEY of M.J. Dallwitz, T.A. Paine and E.J. Zurcher at CSIRO Division of Entomology [2, 3, 5] is an interactive program for identifying a specimen by comparing it with stored description. It works also with an database. However, in order to create keys for this software, the users have to learn the DELTA system that is rather complicated [1].

The SLIKS of Gerald F. Guala [4] is a Javascript program for integrating into websites. SLIKS is being used on USDA website with keys for several plant groups. However, to use SLIKS the users have to know Java Script in order to create data file [11], what is not the case for many botanists.

PlantsVN has been developed under the concept of intelligent plant database and allows the user to either create and manage plant database and to identify plant specimen. This concept means to combine the plant database functions with the utility of plant specimen identification in a database software. Nevertheless, the software is very user-friendly. Even creating the keys for PlantsVN is almost as easy as typing plain text.

This paper describes the technique of integrating the plant identification utility into the plant database software that has been used in PlantsVN-software. The paper also document on

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_11,

the functionality of the PlantsVN-software that is free available at the website of the Institute of Ecology and Biological Resources, Vietnam Academy of Science and Technology [9].

Material and Methods

Delphi XE Professional Workstation ESD (item number: 2010111885211109) of the Embarcadero company [10] has been used to create PlantsVN computer program.

The basic unit of the database is plant picture, PlantsVN uses an array of records to hold information of pictures with following fields: Division, Class, Order, Family, Genus, Species, Picture. Html is the format that PlantsVN uses to displays the database records. In the html file, there are links to text and image (.jpg) files for each taxon that is higher ordered than species (Division, Class, Order, Family, Genus). The users create these files and copy them to the application folder in order to use these links in html.

The format for the text file name is as follows:
TaxonName_E.txt

The format for the image file name is as follows:
TaxonName.jpg

Editing database means changing information of the records. Updating database adds records to the database array. Deleting will erase records from database array.

The identification method in PlantsVN is to compare the user input characters with character sets of taxons stored in key file (*.ide). For the key that accompanies the software, there is a dialog box for user to check specimen characters. For the keys made by users, PlantsVN displays a dialog box with two list boxes for user to choose specimen characters. The identification result is a list of one or more families that have all the characters of the specimen.

The users can create their own identification keys in a text child window called ‘Key file child window’ and store them in a file with the extention ‘.ide’. The format for the identification key file of plant families is as follows:

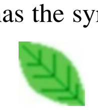
Plant_family_name = \\character1\\character2\\. . .charactern\\

The interaction between identification utility and the database is realized as follows: After identification process, PlantsVN searches records of the database that belong to plant family (or families) in the identification result list, create a html file of them (_plantsVN.html) and display it.

User Interface of PlantsVN

Symbols and Declared File Formats of PlantsVN

The PlantsVN software has the symbol of a



plant leaf, this symbol is assigned to the application file (PlantsVN.exe):

PlantsVN declared following two file formats:

1. The database file format: the file extension is ‘.plt’; the symbol is:	
2. The identification key file: the extension is ‘.ide’; the symbol is:	

Once the PlantsVN software has been installed with using installation file, double clicking on a database file name (*.plt) in Windows Explorer of Microsoft Corporation will cause PlantsVN starting with opening the file.

The Main Window

Main window of PlantsVN (Fig. 1) has a menu bar and a tool bar. The menu items and their functions are presented in the Table 1. The buttons and their functions are presented in the Table 2. The html-file of database records is displayed in this window.

Key File Child Window

Key file child window (Fig. 2) is a text editor and is dedicated for processing the key file. Each line consists of all characters of a plant family and begins with the name of the plant family. Following the name of the plant family are two characters: ‘=\\’. After that are the descriptive characters of the plant family. Each descriptive character ends with an double backslash ‘\\’.

Working with Database

To work with database we have at first to open it by choosing ‘Open database’ menu item or clicking on the relevant button. In the installation package there is an initial database file ‘347.plt’. The main name of the database file is the number of records. The initial database file consists of 347 records of 347 families.

To add a new record, we choose the relevant menu item and fill in the text boxes in the appeared dialog box (Fig. 3).

To delete a record, we choose the relevant menu item and select the record number, then click the OK-button (Fig. 4). Once a record is deleted, the associated with it picture is also deleted.

To edit record, we choose the relevant menu and choose the record in the appeared dialog box (Fig. 5) by changing record number, then edit the information in text boxes.

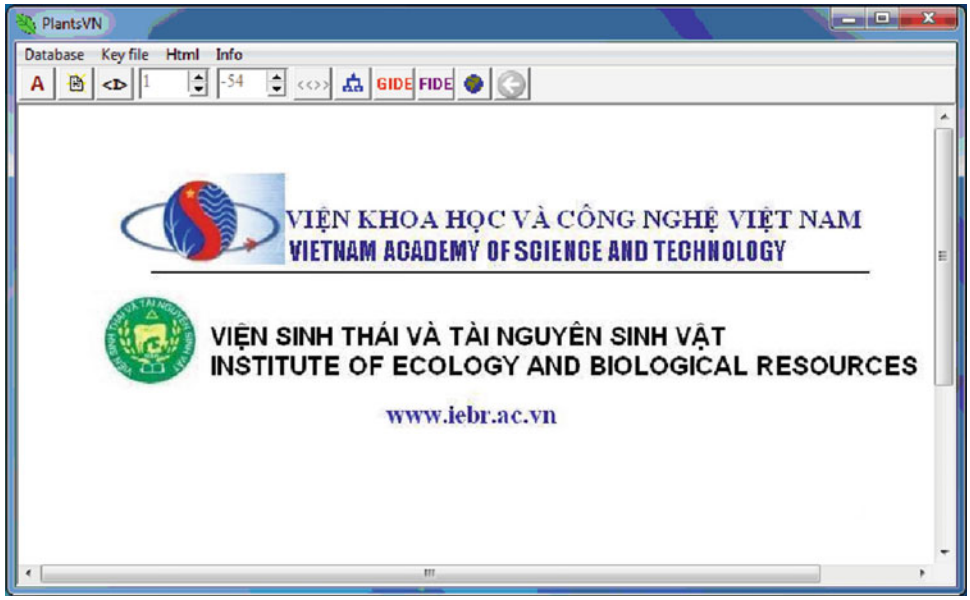
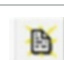
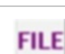


Fig. 1 Main window of PlantsVN

Table 1 Menu items of PlantsVN

Menu/Submenu item	Function
Open database	Open a database file (.plt)
Display database structure	Display the dialog box with structure of database
Add a record	Display a dialog box for adding a new record to the database
Edit a record	Display a dialog box with a record for editing
Delete a record	Display a dialog box for selecting and deleting a record
Statistics of the whole database	Display a dialog box with statistics on number of taxons of the whole database
Statistics of the selected records	Display a dialog box with statistics on number of taxons of the selected records
Identification of flowering plants families	Display a dialog box with characters, user can check the characters of his specimen to identify family
New key file child window	Open a text window so that user can open and edit a key file or compile a new key
Identification with key file	Open a key file and show characters in dialog box, user can choose the characters of his specimen to identify family
Create and display html from database	Create a html file of all records and display it
Fit the picture to window	Click to check or uncheck, if checked the picture will be fitted to window
Computer system info	Display the information of the computer system in a dialog box
About	Display information about the author of the software

Table 2 Buttons on the toolbar of PlantsVN

Button	Function
	Open a database file (.plt)
	Switch on/off the database browsing mode
	The first: Select the record The second: Scale the picture
	Switch on/off browsing pictures of a species
	Display the dialog box with structure of database
	Display a dialog box with characters, user can check the characters of his specimen to identify family
	Open a key file and show characters in dialog box, user can choose the characters of his specimen to identify family
	Create a html file of all records and display it
	In html mode: go to previous page

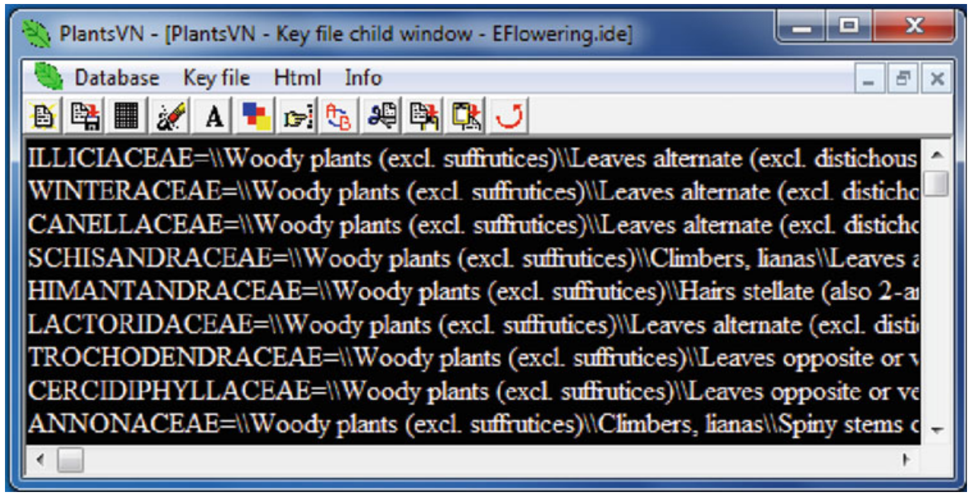


Fig. 2 Key file child window for key file processing

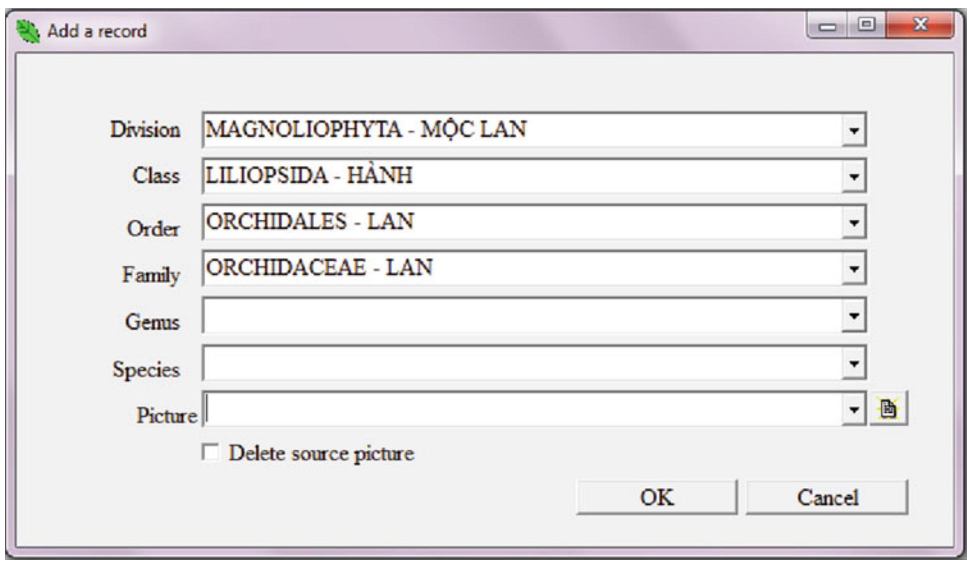


Fig. 3 Dialog box for adding records

To look at the database structure we choose the menu item ‘Display database structure’ or click on the relevant button. In the appeared dialog box, we can choose to see different taxons (Fig. 6). Once we click on one taxon, the next lower ordered taxons will be displayed in the next column.

Click on the name of a taxon and then click on the column name on the top of the column (Division, Class, Order, Family, Genus or Family), PlantsVN will display all its lower ordered taxons in html-format (Fig. 7).

In order to browse through pictures of a species, we double click on its name in the last column of the database structure dialog box. The first picture of the species will be displayed in the main window (Fig. 8). After that we click on the ‘Browse species pictures’ button to change the pictures.

While browsing pictures of a species, we can change their size (by using the relevant button) and move them around using the mouse (by keeping mouse down and moving it).

To switch on the database browsing mode we click on the relevant button. While being in this mode, we can use the relevant up-down button to change the records. Once a record is selected, the taxon information will be displayed in the title bar and the associated picture will be displayed in the main window. We can change the picture size and move it around like during browsing pictures of a species.

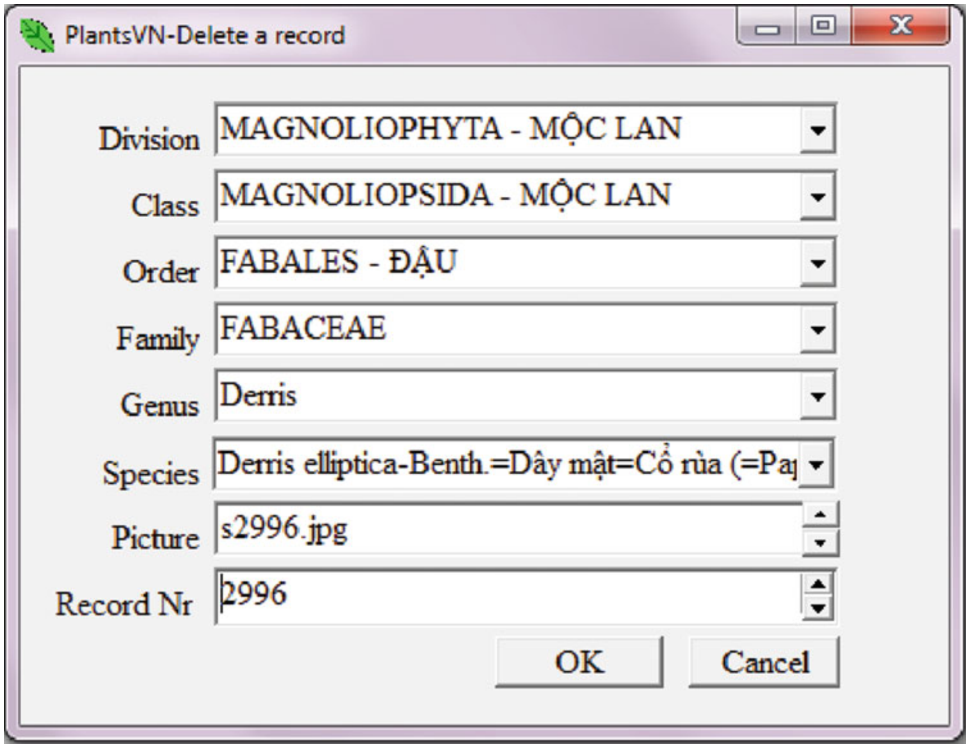


Fig. 4 Dialog box for deleting records

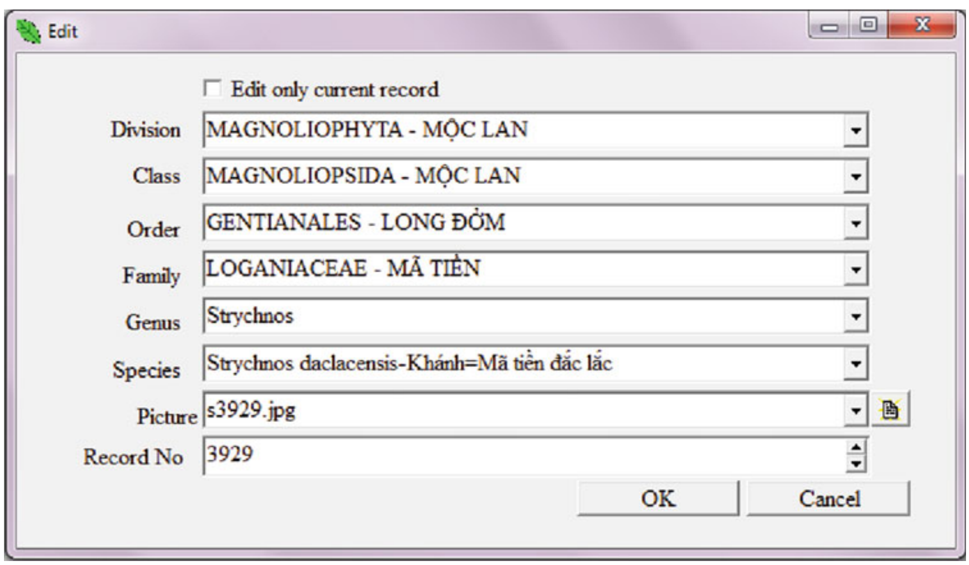


Fig. 5 Dialog box for editing records

We can get statistics either for the whole database or for the selected records by choosing relevant menu. The results will be displayed in a dialog box (Fig. 9).

Identifying Plant Specimen

When we choose the menu 'Identification of flowering plant families' or click on the relevant button, a dialog box with check-button-characters will appear (Fig. 10). Click to check the characters that the specimen has, then click on the OK-button, the matched taxons will be displayed in html-format. This procedure is applied only for the software accompanied key.

Choosing the menu 'Identification with key file' or clicking on relevant button will cause the PlantsVN displaying the dialog box for identification with key file (Fig. 11).

In order to work with a key file, we click on the Open button on this dialog box and choose the key file in the

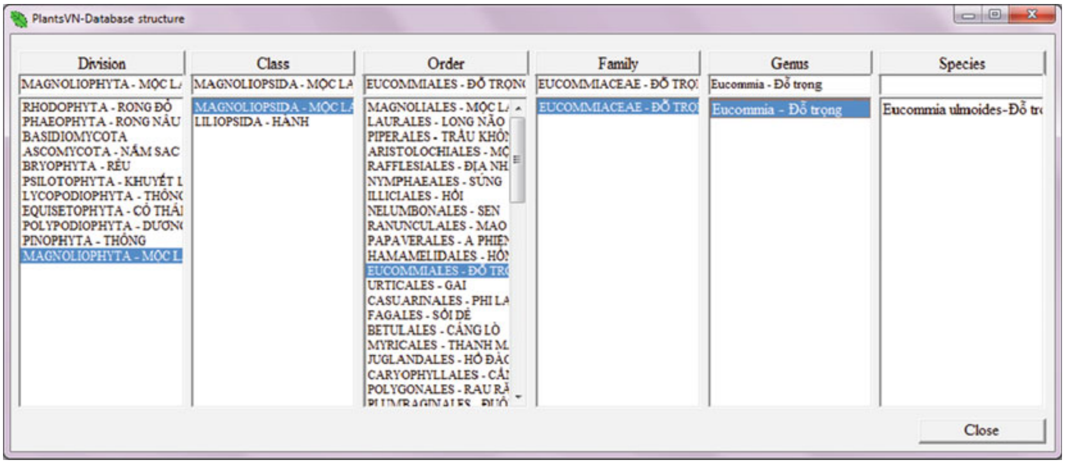


Fig. 6 Displaying database structure dialog box

Fig. 7 Displaying the lower ordered taxons of Typhales

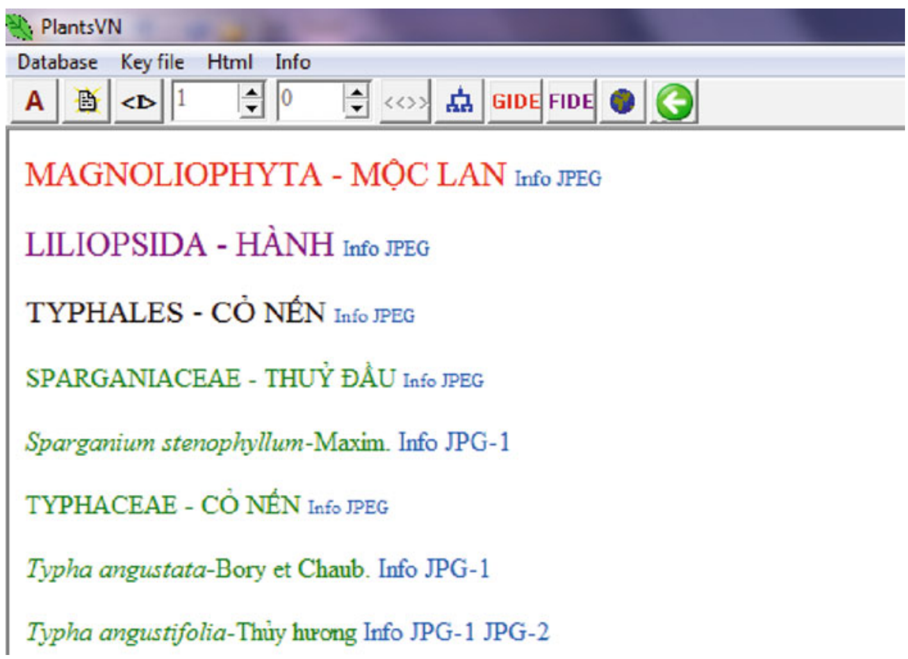
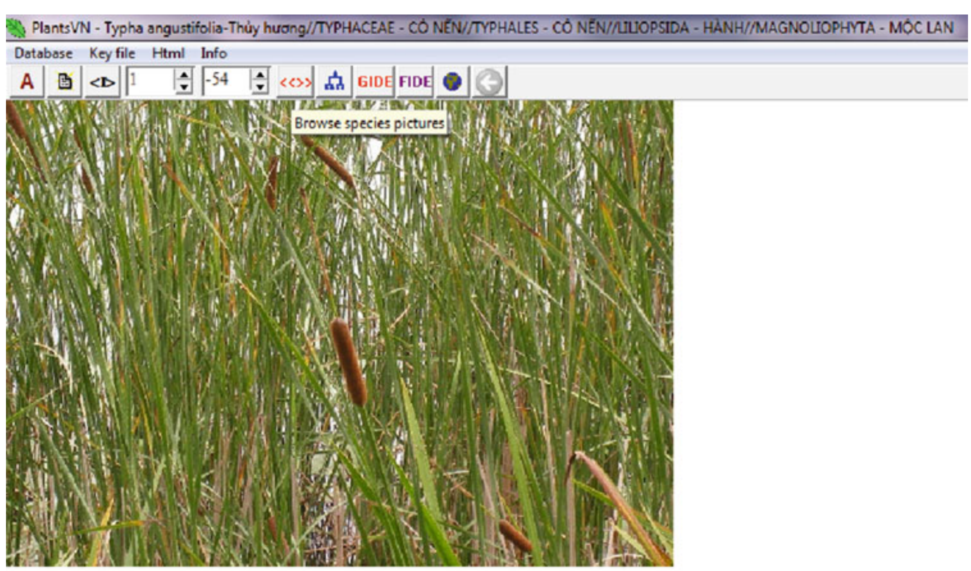


Fig. 8 Browsing pictures of *Typha angustifolia*



appeared open file dialog box. PlantsVN will open the file, display all the characters of the key file in the left list box. We choose the characters that match our specimen and click the arrow button to transfer them to the right list box. After that we click on OK-button to order PlantsVN to finish the identification process. If records have been selected before (by choosing taxon, or even by identification), we can order the PlantsVN to search matched taxons only from these records by checking the check-button at the bottom of the dialog box.

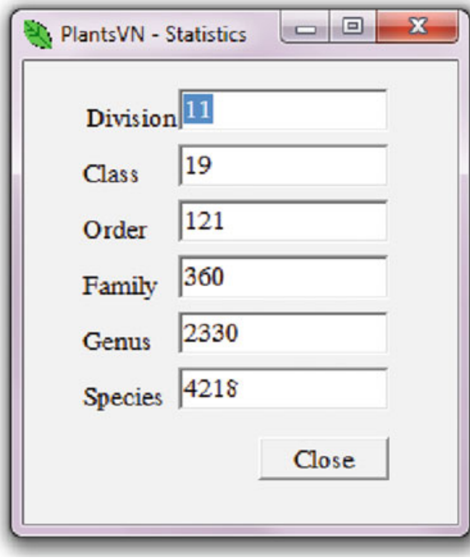


Fig. 9 Statistics results

Discussion and Conclusions

A personal database with integrated identification utility might be very useful for the people involved with plants. Creating, updating and browsing a plant database are helpful for remembering the species, however referencing the database with using integrated identification utility might contribute more to the success of plant studies. That is why PlantsVN might be useful for students and plant scientists.

Most keys are now created for the plant taxons in the form of dichotomous key. But dichotomous keys are less flexible than polyclave ones. One of the reasons might be the lack of a user-friendly tool for creating and using polyclave keys. Regarding these reasons PlantsVN might be useful for plant taxonomists.

Acknowledgement The Vietnam Academy of Science and Technology has supported this work through the project VAST04.08/13-14.

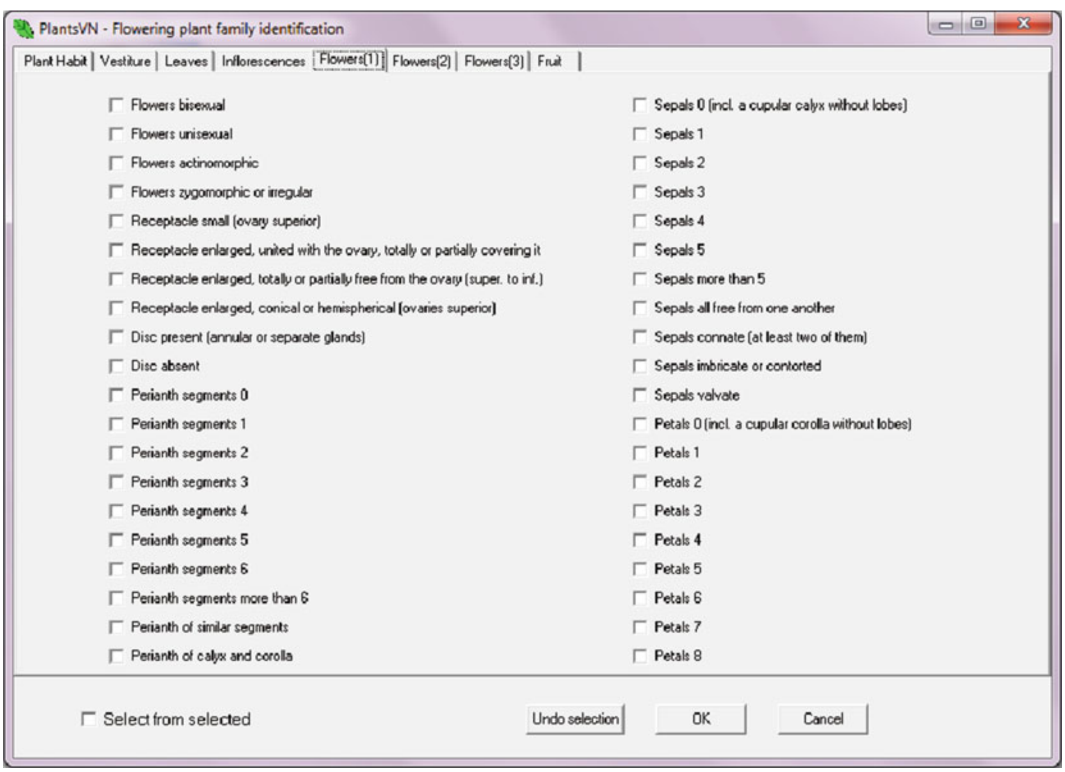


Fig. 10 Dialog box for identification of plant families

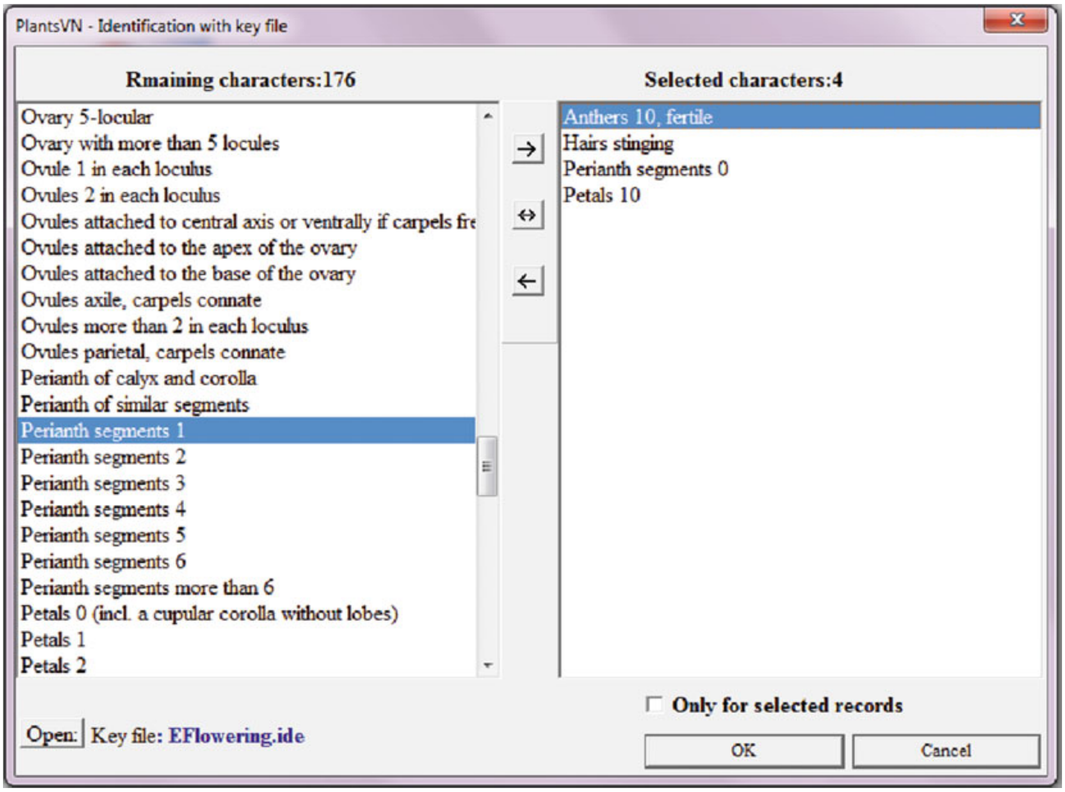


Fig. 11 Identification with key file

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An Automated Tool to Support the Software Design Process

Fernando Uceda-Ponga and Gerardo Ayala-San Martin

Abstract

In this paper we present FESA, a Forward Engineer and System Analyzer, that supports the software design process based on the Model Driven Engineer paradigm. We show that by following the proposed ORDEREXP design rules during the elaboration of the ER (Entity Relation) diagram, FESA is able to construct the software prototype. ORDEREXP supports the software designer by providing more information about the modeled process and how final user graphic interface of the system will be, while preserving the DB scheme normal form. Design patterns are used by FESA for supporting the analysis of the ER diagram, in order to obtain additional recommendations and optimizations to the model.

Keywords

Automated • Software design • Software prototype • Graphic interface • Design patterns

Introduction

The evolution of hardware and software platforms has derived in a software design process that has become more complex. Current research in the area of Model Driven Engineering (MDE) [1] is oriented to reduce the redesign of software due to changes in the software and hardware platforms.

Today, there's a huge demand on software. But not any software; the demand is for software that can be used across diverse platforms. Several desktop developers are getting started with mobile software development. Unfortunately, to share part of the code across platforms is not possible in the majority of the cases. There are many reasons why to share logic and code across platforms is desirable.

Code sharing should be independent of the implementation, regardless of whether the original application was written for a desktop, tablet or mobile devices. A common scenario is to start the developing process from one platform, and then port that implementation to other. If a given application is actually used and running on PC today is desirable to have it also on a mobile device, or vice versa.

The priority of MDE is to provide the designers with tools that help them in the process of software design and its corresponding implementation, by generating the code automatically. This is called forward engineering. In this way, automatic tools should allow the software designer to focus just in his software model, at a level of abstraction more manageable an easy to comprehend. Theoretically, this will enable the system designer to share much of the developing time and resources in different implementations of the same software.

In an effort to reach the MDE goal concerning passing from a conceptual model to a ready to use system, designers commonly use a Framework-Specific Modeling Language (FSML) [2]. FSMLs are less generic because they were created to have an easy conversion of the abstract models to their implementation and code, for a specific programming language or platform. Even less generic FSMLs are commonly used because reduce implementation time for a specific platform and allow the designer to have a greater degree of abstraction to simplify the design process. FSMLs

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_12,

are not the only option. UML provides a structured and generic language to model systems. Unfortunately UML is not easy to convert into code. To overcome this problem there is a subset of UML known as Executable UML (xUML) [3]. In a step forward to the MDE goal, we created FESA (Forward Engineer and System Analyzer). FESA has the ability to create systems for different platforms from the system model.

Related Work

Works with the primary goal of create tools that convert models to running code, or focus in the creation of modeling languages and are part of the same research area of this work are:

PETUT-MOO (Performance-Enhancing Tool using UML Transformations and Multi-Objective Optimization) [4]. The preliminary results of the CRN (Car Radio Navigation system) case study show the possibilities and viability their work in fact they report a 50 % reduction in processor load by using the architecture proposed by their tool against the original model that the system had they focus on optimization rater that the code generation.

E-R Modeler [5] is implemented as an Eclipse plug-in that provides an E-R (Entity-Relationship) diagram modeling tools. The plug-in also provides database connection and schema creation capabilities from within Eclipse. *E-R Modeler* only generate code for the SQL scripts it does not create any software units to manipulate de database.

Transforming UML Static Models into Object-Oriented Code in this work [6] they describe a framework for code generation from diagrams in GSBL (Generic Specification Base Language). The main contribution of their approach is the fact of deriving knowledge from UML models with annotations in OCL (Object Constrain Language), to verify implementations against specifications. They focus on validation rather than creation.

CLAFER [7] the premise of this work are usage scenarios mixing feature and class models together, such as representing components as classes and their configuration options as feature hierarchies and relating feature models and component models using constraints. Representing both types of models in single languages allows us to use a common infrastructure for model analysis and instantiation CLAFER is a very good work but it lacks forward engineer capabilities.

Our work aims to fill the gaps currently present in this research area.

Our Work

We created a FESA to reach MDE goal of having a system generated from it base model. FESA use enhanced ER diagram as the system base model to generate software units that compose a system. FESA architecture is shown in Fig. 1.

FESA Design Rules

We propose a set of design rules that are called ORDEREXP (Order Assurement Rules for Designers of Entity Relation Diagrams for an Express Development) as a set of rules to be followed by the designer so he can develop more expressive and ordered entity relation diagrams. Having this, FESA is able to infer accurately the requirements and generate an appropriate SQL and interface code. FESA ensures that the design had been elaborated following the ORDEREXP design rules. ORDEREXP use an aggrupation component that we call layers.

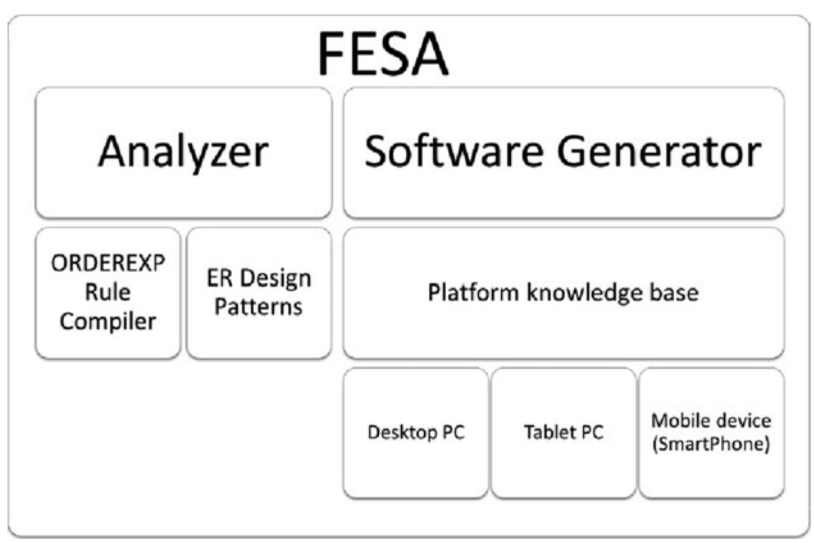

Fig. 1 FESA (Forward Engineer and System Analyzer) architecture

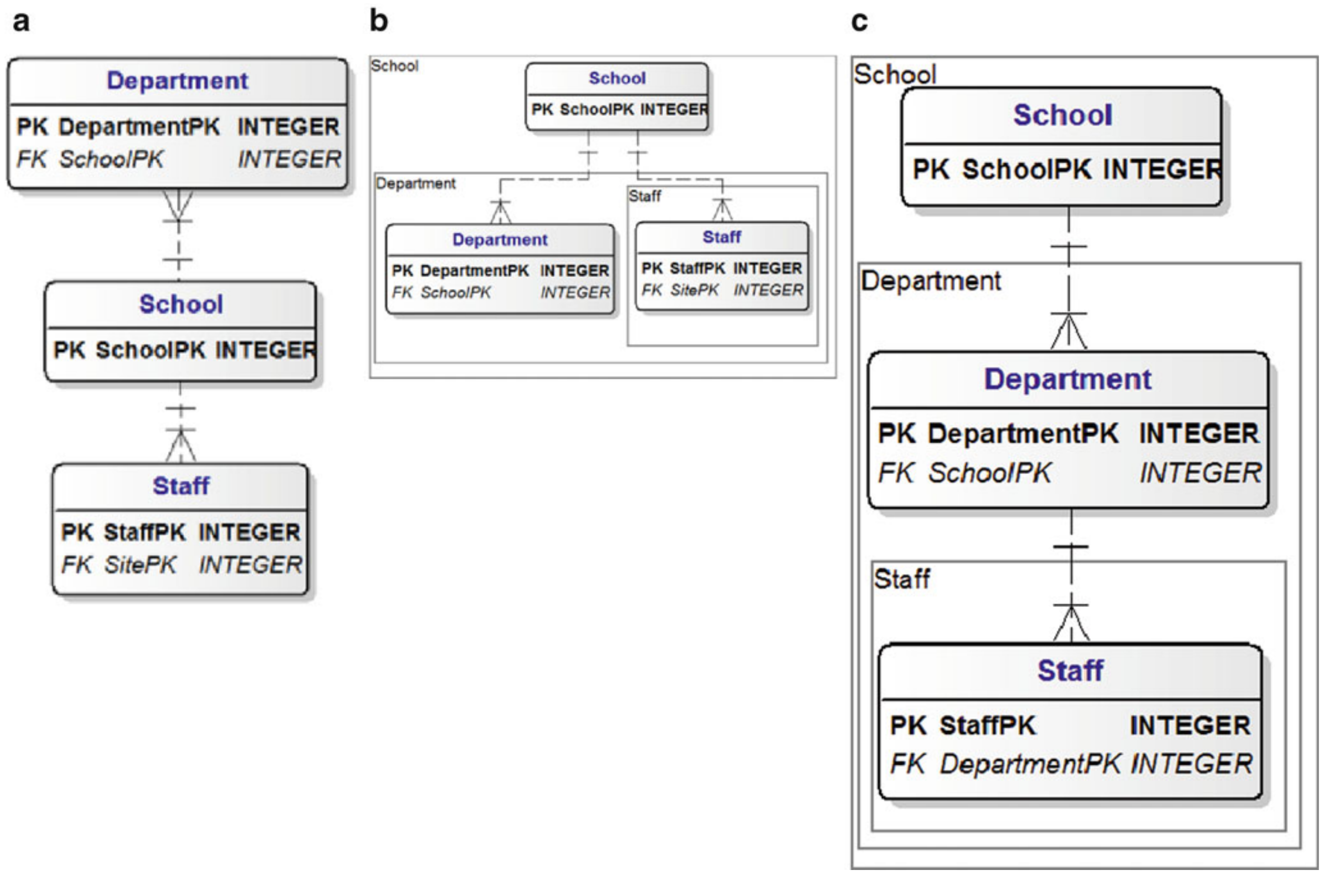

Fig. 2 In image (**a**) we see an entity relation diagram using crow's foot notation [9], image (**b**) we see the same diagram organized in layers according to the ORDERXP rules and representing the hierarchy and the process that should be used based on the requirements. Image (**c**) show the diagram corrected by FESA. Using the information of the layers FESA found the diagram to have the fan trap [10] problem

Layers

We propose that each entity relation diagram that a software designer creates must use conceptual boxes that group one or more entities. These boxes are called layers.

Layers are divided into three types, according to the way they group the entities of the ER diagram:

(a) *Entry point layer*:

Layer that has the same name of an entity placed inside it.

Layer that has the same name of layer placed inside it.

(b) *Module layer*:

This is a Layer that does not have the same name of the entities or layers inside it.

(c) *Subentry point layer*:

Consist of an entry point layer placed inside another entry point layer.

Layers should be used to represent hierarchy of the entities and whenever an entity should have a separate software unit that manage it or the entity should only be manage trough other entities software unit. Layers must express the intended modeled process beyond what an entity relation diagram express. An example of how the layers are used can be seen in Fig. 2 where we show that the use of layers provides information about the correct order of the diagram.

ORDEREXP Design Rules

1. Every entity must be placed on a layer: The purpose of this rule is to give clarity to the ER diagram and to let FESA know when an entry point should be created for an entity. Following this rule in a hierarchical organization represent the process and importance of the entities, FESA use this information when analyzes the design.
2. Entities that are considered the main object should be placed in an entry point layer: This will make FESA see the entity considered the entry be the father entity of all referenced entities that are in the same layer or in sub layer of the entry point layer.
3. Entities that should be affected by the same software unit should be grouped by a single layer independently

if the entities need an entry point layer: When a process model an object containing other objects and the contained one are dependent of the father. The purpose of this rule can be seen in Fig. 5 where entity Object1 contains ObjectsInObject1 and we need that the ObjectsInObject1 entity could only be manipulated through its parent entity.

4. Entities that belong to software units that are considered as parts of the same area must be placed in a *Module Layer*: This rule purpose is to describe how the features and software units should be accessed by user. Let's think in traditional software, usually they group it functionalities in menus, module layer tells FESA software generation engine that the software units created for the entities on that module should be placed on the same menu.

Entry points: FESA generates the model, view and controller of the prototype. An entry point is a component of the generated view, and is the only way the final user will be able to interact with the data of the entities.

FESA also generates the controller of the prototype, as software units to manage each entry point based on the layers.

To create the model FESA relays on a plug in system that provides an abstraction layer to all FESA components that will interact with data. The plugin system allows that all components created by FESA use the same data function call while the plugins systems manage the particular data source operations. Currently FESA have data plugins to work with Microsoft SQL, MySQL and remote storage using web services SOAP calls. When FESA create the model it passes the creation and relations sentences to FESA data manager, the data manager will create the database creation script depending on the active plugin. We choose this design pattern to make FESA independent of the data source type.

In addition to the generated software unit based on the entry points FESA generates a main interface that will group the software units together to form a sole system.

The main interface groups software unit based on the *Module layers* present in the diagram. In order to allow future enhance and easy change of the software units, all software units grouped in the main interface are loaded by the main interface at runtime and are used as plug ins to avoid strong binding and easy extension.

FESA Analyzer

The FESA Analyzer divides the diagram into its smaller units. For each one of these units the analyzers test that the ORDEREXP rules were properly followed and that the design does not contain ambiguity or pattern violations that are avoided by proper following of the ORDEREXP during the design process. When a design contains ambiguity or pattern violations the analyzer provides possible solutions for the situation. In this steps based on its knowledge base FESA will suggest one or more possible solutions depending on the rules and actions stored in its knowledge base.

FESA analyzer does not modify the model automatically unless designer chooses to let FESA run in a completely automated way. FESA standard behavior is to hint the error and provide suggestions for fixing it leaving the decision of which solutions use in hands of the designer, if the error is not fatal and is just something that could be done better FESA analyzer will allow software units generation even if the advises are ignored, for critical errors that will lead to a design flaw the analyzer will not let the process to continue until the errors are fixed or designer choose to let FESA do proper corrections automatically in order to accomplish software generation. Let FESA fix errors or improve the model automatically prove to be a good choice in our experiments. FESA analyzer correctly generates software that meet 81 % of the user requirements without human coding, also is faster because in many occasions fixing an error lead to a new ambiguity been exposed. Following the hierarchy provided by the layers of ORDEREXP FESA analyzer fix the model giving priority weight in a top down search with backtracking for a complete automated search that prevent that a given error fix does not undo any of the previous applied correction to a layer or entity that have a higher hierarchy. This will avoid dead loops.

FESA Software Generation

Software entities generated by FESA intend to infer the logic and process of the system that is been modeled. FESA generate the structures using SOA architecture with a Model View Controller (MVC) perspective. In order to achieve our goal of having FESA able to create system prototypes that can target different platforms, we use the web design approach. For this FESA contains a knowledge base about how desktop systems should look like and behave, how tablets supposed to and how mobile device like phone should do. The behavior, look and feel rules of the software units generated by FESA are expressed in CSS3 styles, and HTML5 + JavaScript objects.

The steps involve in a system generation using FESA are described as following.

Design a System Model

In this step the designer should create an ER diagram following the ORDEREXP rules. The creation is done using a simple GUI tool that we created on .Net 4. This tool exports the model to a XML file. The design could be done entirely on XML using any text editor since FESA read the XML file to perform the analysis.

After the design is done the system generation processes in FESA cover the following steps.

Model Analysis

After the design is exported to XML FESA analyzer loads the XML file and search for possible enhances or design errors. FESA analyzer will search for design error, ORDEREXP rule violation, good practices suggestion, and possible improvements. When no errors are found in the design FESA will invoke the platform knowledge base. The platform knowledge base loads different design patterns depending on the target platform. The knowledge base contains interaction rules, software base component and software design patterns used for each specific platform. The knowledge is stored in a late binding plug in system to allow the inclusion of new target platforms to FESA software generation capabilities (Fig. 3).

Generate the SQL base model. FESA software generator creates a SQL script that contains the model of the system. In some cases the analyzer need to create views and SQL procedures to manage operations.

Select a rule set. Currently FESA does not generate software units for different platforms at the same time although the database model is the same. This is because some platforms, like Smartphones, have limited database capabilities and this requires additional functionalities in the persistence manager. FESA have generation rules for Desktop PC, Table PC, Mobile device (Phone). In this step the designer is asked to choose a target platform and use FESA proper generator.

Generate the persistence manager. FESA philosophy is modularity. Software units generated by FESA does not access database directly, all units use the persistence manager. Using a persistence manager layer allows the data source to be changed just by changing the database plugin without the need of changing the software units. To allow FESA the creation of more useful and versatile software, not only direct databases can be managed by the persistence manager, we include in this module a SOAP plugin to allow rich internet applications.

Generate the system GUI. FESA generates the graphic user interface (GUI) of the system based on set styles that have to be defined in FESA knowledge base. Figs. 4, 5, and 6 illustrate the basic idea behind the GUI generation. The styles are different depending on the selected platform and vary between them; examples in Figs. 4, 5, and 6 are illustrative. The look and feel of the application along with the behavior can be easily change since HTML5 and JavaScript code is used for the View of the system. FESA only uses W3C standard instruction to warranty cross platform compatibility. We choose HTML5 since it's a standard and runs on many platforms.

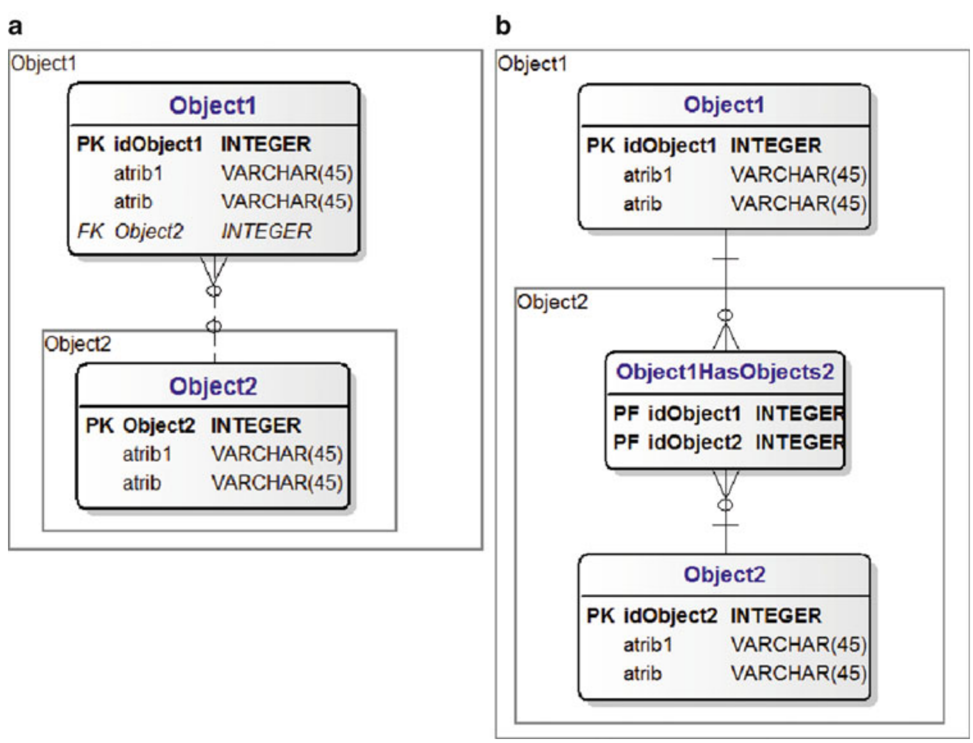

Fig. 3 In (**a**) we see a design made where the hierarchy of the layers says that Object2 is contained in Object1 but the relations says Object1 have a Object2 relation that is not identifying. This is contradictory in (**b**) we see an example of one of the possible solutions suggested by FESA. FESA will model the relation as a conceptual many to many because it function correctly with the proposed hierarchy

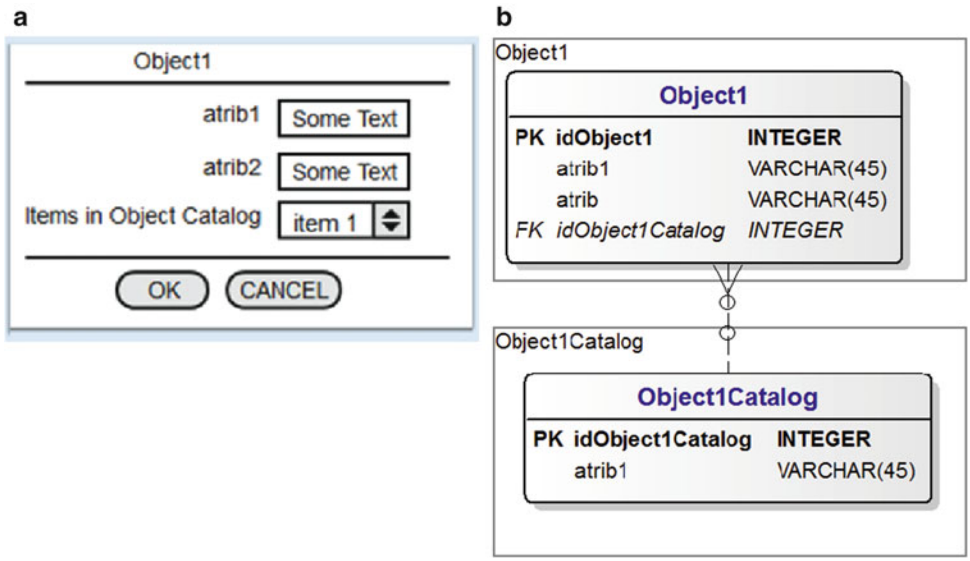

Fig. 4 FESA generation rule BaseUnit. For entities related and grouped as we see in (**b**) FESA will generate a software object that will have a user interface resembling (**a**). Final look of the user interface will depend on the CSS defined or chosen from FESA design bases

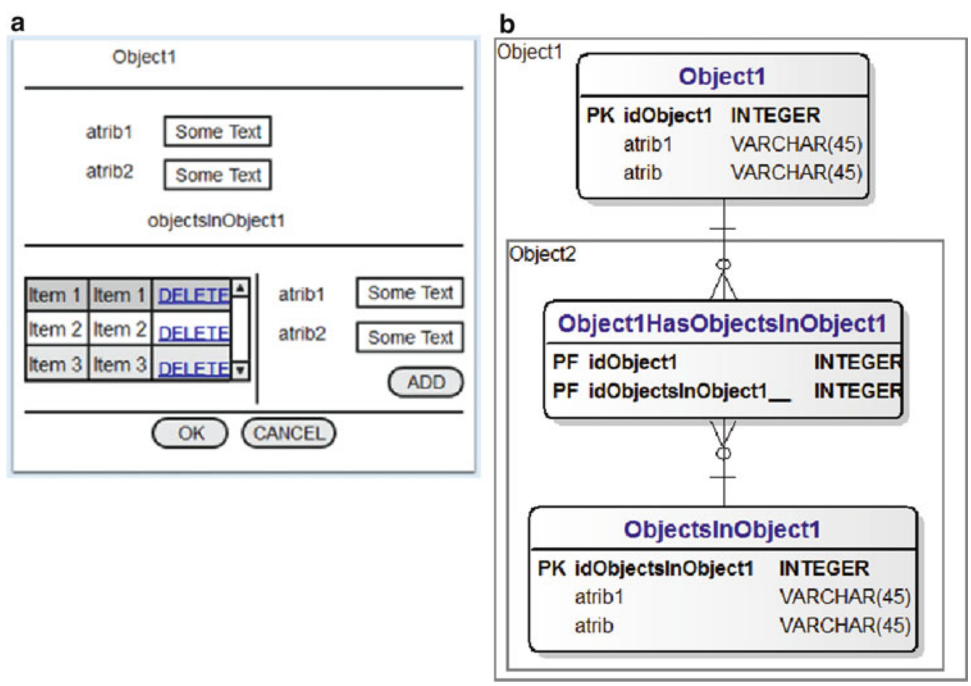

Fig. 5 FESA generation rule ContainedUnit. For entities related and grouped as we see in (**b**) FESA will generate a software object that will have a user interface resembling (**a**) We see that the middle entity that allows a conceptual many to many relation is not present in the user interface, this is because FESA will use this information in the controller. Also because ObjectsInObject does not contain an entry point layer the only way to manipulate data stored in these entities is by accessing first to the Object1 software unit

To create Desktop PC software FESA builds a loader that wraps the HTML and lunch it as a standard executable file.

Experiments

To test FESA capabilities we decide to use FESA for the generation of a school administration system that had a database consisting of 90 tables and 183 relations between them. All software documentation, final system and source code to compare FESA was provided by Sorcery Solutions® [10]. Software documentation consists of uses cases, DFD (data flow diagram) diagrams, class diagrams, ER diagrams, a functional requirements document and nonfunctional requirements document.

We analyze the documentation and test the provided software to understand what was required to do. In our analysis we take the provided database scheme and apply the *ORDEREXP* rules to it.

This system had requirements and UML diagrams to describe desired functionality. For experimentation we run FESA over the database scheme as it was provided and we just add the layers according to the *ORDEREXP* rules.

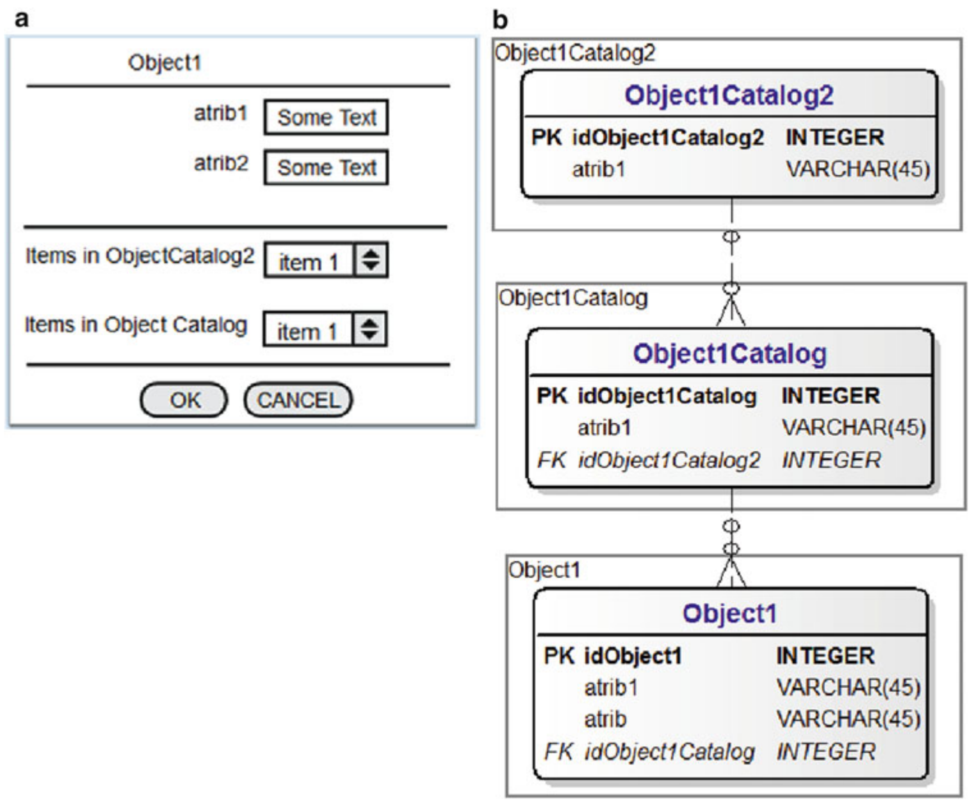

Fig. 6 FESA generation rule BackTrackingUnit. For entities related as we see in (**b**) FESA will generate a software object that will have a user interface as shown in (**a**). We see that the Object1 unit have reference to theObject1Catalog2 even when this data is not explicitly stored in the entity, FESA does this to enhance user usability of the software. Since each entity have its own entry point layer FESA will also generate software units to manage each entity separately

Table 1 Comparison of the needed features in for the system and the features generated by FESA

	Required functionalities	Involved entities	Correctly generated functionalities	Precision
Courses administration	40	10	35	0.88
Students administration	36	15	30	0.83
Fathers or legal guardian administration	20	6	17	0.85
School administration	30	30	20	0.67
Study plan administration	12	15	7	0.58
General system administration	49	20	48	0.98
Administrative employees administration	20	17	13	0.65
Teachers administration	27	16	21	0.78
Payments and accounting	35	17	18	0.51
Grades administration	37	19	33	0.89
School reports and status overview	43	63	40	0.93
Total number of functionalities				349
FESA total correctly generated functionalities				282
FESA overall precision				**0.81**

We decide to let FESA fix any error or ambiguity in a completely automatic way. The provided software is desktop pc system so we choose desktop pc generation (it is important to remark that all features that FESA can generate for a platform will be available to other as long as the knowledge base contain the base rules). We test the FESA generated software side by side with the provided system and verify the present functionalities in both systems. Detailed results of the analysis can be seen in Table 1 for the overall system FESA correctly generated features for 81 % of the specified in the requirements document and that were present in system used for comparisons. In some cases FESA provide better functionality than the handmade counterpart specially because all the system had the same interaction rule and overall design making it fell more integrated and as a single piece. These occur because commonly many people are involved in the creation of software and sometimes individual preferences are shown on the module in charge of a person making little divergences in the system design.

Functionalities that FESA was not able to correctly generate involve role management, taxes and some complex study plan rules.

Conclusions

In this paper we presented FESA, a Forward Engineer and System Analyzer tool that supports the software design process based on the Model Driven Engineer paradigm.

With the use of the proposed *ORDEREXP* rules FESA is able to construct a software prototype that achieves almost all the specified requirements. FESA supports the software designer by giving them a tool that let them have a system prototype without typing a single line of code. The use of *ORDEREXP* makes clear in the ER diagram information about the modeled process and the interfaces of the system while preserve the database normal form.

Design patterns in FESA knowledge base are used to support the analysis of the ER diagram not only in theory but also in an implementation perspective. This allows FESA to obtain additional recommendations and optimizations to the model.

Our results show that, FESA is able to automatically generate a software prototype accomplishing 81 % of the software requirements. Features not correctly generated by FESA were mainly because the process was not possible to be correctly described using only the provided ER diagram and the *ORDEREXP* rules. We did not modify the ER diagram and let FESA work with it as it was originally released. We do this to prove FESA in a realistic scenario using a design that was approved and used in production. FESA outputs a fully organized HMTL5 and JavaScript project that can be used as starting point for system development; using a FESA generated system as base will reduce manual coding.

FESA advantage is that does not require the learning of a FSML because it works with the ER schemes. Is important to remark that FESA software generation allows addition of different programing languages outputs by adding a plugin.

To pinpoint FESA capabilities we compared FESA provided features with other relevant work done in the software engineer area, results of the comparison are show in Table 2. In our comparison we evaluate the following aspect of the work:

(a) *Creation*: The work provides a tool to create or modify models.
(b) *Analysis*: The work checks the models for completeness, inconsistencies, or errors and warnings.
(c) *Transformation*: Proposed work can convert models into other models or, documentation or code.

Table 2 Comparison of works that provide MDA tools or support against FESA features

	Creation	Analysis	Transformation	Forward engineer
Ficco et al. [11]		X		
Landan et al. [4]			X	X
E-R modeler [5]	X		X	X
PerOpteryx [12]	X	X	X	
DiscoTect [13]		X	X	
Blanc et al. [14]		X		
Thompson et al. [15]		X	X	
Cortellessa et al. [16]		X	X	
FESA	X	X	X	X

(d) *Forward Engineer*: The work can convert models running software.

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A Low-Cost Force Measurement Solution Applicable for Robotic Grippers

R.V. Sharan and G.C. Onwubolu

Abstract

Industrial robots find profound usage in today's industries and an important characteristic required of such robots in pick-and-place operations is determining the gripping force when picking objects. This paper presents the use of a FlexiForce force sensor for measuring the gripping force when picking work-pieces using the two-finger gripper of a pick-and-place robot. This thin and flexible analogue force sensor is capable of measuring both static and dynamic forces. It has an output resistance that is inversely proportional to the applied force and easily calibrated and interfaced to a microcontroller with an in-built analogue-to-digital convertor. Through experimentation, a relationship between the weight of work-piece to be gripped and the force to be applied for gripping was determined. This was used to successfully manipulate work-pieces of various shapes and sizes up to the robot payload of 0.5 kg. Analysis of various forces acting on the work-piece was also carried out.

Keywords

Force sensor • Piezoresistive • Industrial robots • Pick-and-place

Introduction

Humans have the amazing ability to safely grasp objects of various shapes and sizes by only applying enough force. While such work can be carried out with ease and without much thought by humans, getting a robot to perform a gripping task can become very complicated depending of the application. Applying excessive gripping force when gripping a delicate object can damage the object or damage the gripping mechanism and actuator in the case of a rigid object.

The ultimate aim of robotics research is to develop intelligent systems that can operate autonomously and probably the key autonomous feature required of industrial robots in pick-and-place operations is applying the right force when picking objects. In the work reported in this paper, the use of a Tekscan FlexiForce force sensor to measure the force when gripping work-pieces using the two-finger gripper of a five degree-of-freedom pick-and-place robot, reported in [1–3], is illustrated.

With the incorporation of a vision system in its workspace, the robot is used for picking and placing work-pieces of different shapes and colors scattered on its work-plane, as specified by the user through a graphical user interface (GUI). The work-pieces vary in weight but weigh less than or equal to the maximum payload of 0.5 kg. The force sensor has been mounted on one of the gripping fingers and it sits below the rubber gripping pad.

While there are many off-the-shelf force sensors which can be used for such applications, the FlexiForce force sensor offers advantages such as low-cost, ease of mounting since it is thin and flexible, varying force range, and easy interface to control devices which other sensors may not offer. It finds usage in many applications and research such as robotics [4], airbags [5], surgery [6], toe forces [7], and knee forces [8].

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_13,

Sensor Overview

The FlexiForce force sensor, shown in Fig. 1, is a piezoresistive type where the output resistance is inversely proportional to the applied force. Piezoresistive force sensors have an advantage over the capacitive types as they require simple read-out circuitry [9]. It is ultra-thin with a thickness of 0.203 mm, 14 mm wide and available in four different lengths with minimum and maximum sizes of 51 mm and 197 mm respectively. The sensor is also available in three different force ranges capable of measuring up to 440 N which can be increased further with the implementation of excitation circuitry as given in [10].

The sensor employed in this work is the A201 model with a length of 197 mm and a force range of 0–110 N. The active sensing area, which is circular in shape, is 9.53 mm in diameter and it comes with a three-pin connector. It offers a repeatability of less than 2.5 % of full scale with a response time of less than 5 microseconds. Currently, a package of four of this product is available at US$65 [10].

Force Measurement

The output at the force sensor terminals is resistance and when force is applied to the active sensing area of the sensor, the resistance at the terminals decreases from an infinite value at no load. Through experimentation, a relationship is determined to relate the load to be gripped and the sensor resistance. Firstly, masses at increments of 100 g, up to 1.0 kg, were put in between the two gripping fingers and then gripped until the load was fully grasped. A plot of the output resistance of the force sensor against the load being gripped is shown in Fig. 2.

Fig. 1 FlexiForce force sensor

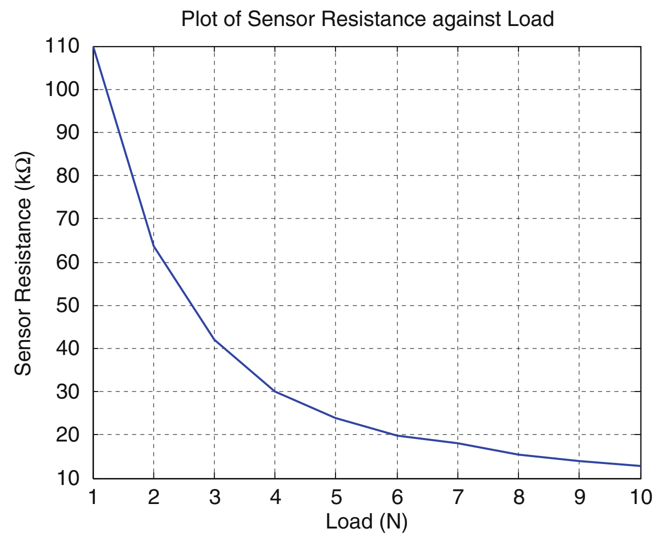

Fig. 2 Relationship between the load being gripped and the force sensor resistance

Mathematically, this hyperbolical relationship is approximated using Microsoft Excel as

$$R_S = \frac{115.61}{W^{0.9618}} \tag{1}$$

where W and R_S denote the weight of the load and the resistance at the terminals of the force sensor respectively.

The in-built 8-bit analogue-to-digital (ADC) convertor of the PIC16F877 microcontroller is used for force measurement. However, the ADC reads analogue voltage values and due to the small force range considered for this work, a simple voltage divider circuit, with a source voltage V_S of 5 V and load resistance R_L of 20 kΩ, was preferred for converting the sensor resistance to voltage over the circuit given in [10]. The load voltage is then given using the voltage divider rule as

$$V_L = \frac{R_L}{R_S + R_L} V_S \tag{2}$$

where R_S can be found using (1) for the load to be gripped.

The force sensor is connected to the analogue pin A0 of the microcontroller. Since the microcontroller has an 8-bit ADC, the input voltage from the force sensor V_L has a range from 0 to 255 corresponding to $0 - 5$ V respectively. The input voltage corresponding to the 8-bit value v is then determined as

$$V_L = \frac{v}{255} \times 5. \tag{3}$$

However, (1) does not give the relationship between the gripping or sensor force and the load being gripped.

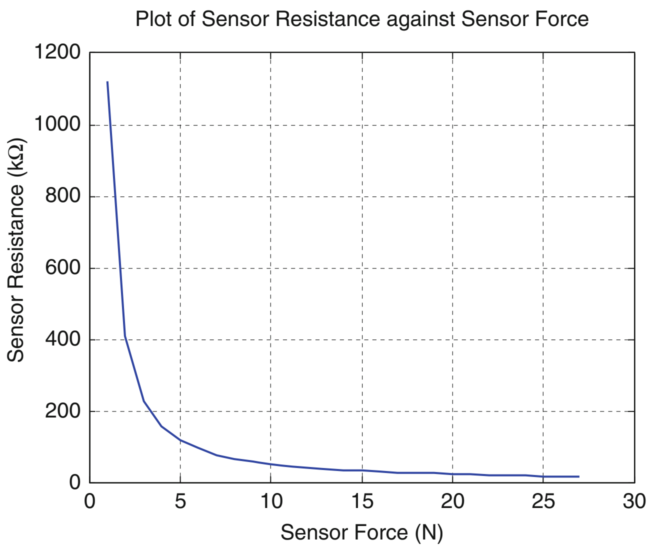

Fig. 3 Relationship between the sensor force and the sensor resistance

Therefore, another experiment is performed to determine this relationship by applying known forces normal to the sensor. Similar to the previous experiment, the force sensor resistance decreases hyperbolically with an increase in the force on the sensor, as shown in Fig. 3.

The relationship between the sensor force F_S and the sensor resistance R_S is approximated using Microsoft Excel as

$$R_S = \frac{933.64}{F_S^{1.2452}}. \tag{4}$$

Equating the two resistances from (1) and (4) and making F_S the subject of the formula yields

$$F_S = 5.35W^{0.7724}. \tag{5}$$

Hence, (5) is used to estimate the force needed to grip work-pieces of different weights.

Analysis

The free-body diagram depicting the gripping of a work-piece using the two-finger gripper of the robot is shown in Fig. 4. The two normal forces $\mathbf{F}_N$, are the forces applied by the gripping fingers while the friction force between the gripping fingers and the work-piece is designated as $\mathbf{F}_R$.

Assuming that just enough force is applied to grip the work-piece and that the two normal forces and the two frictional forces are same, with a payload of 0.5 kg or 5 N, the frictional force $\mathbf{F}_R$ will be approximately equal to 2.5 N. Also, the normal force, which is equal to the sensor force, is determined using (5) to be 18.55 N.

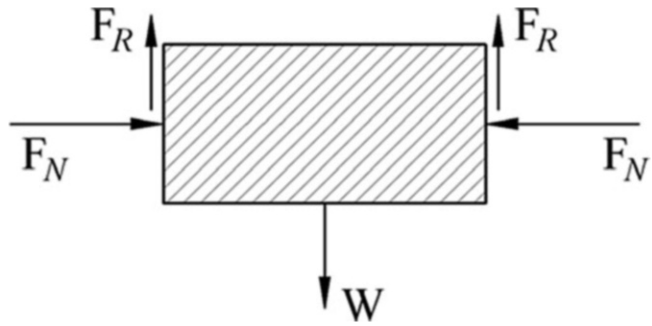

Fig. 4 Free-body diagram showing the forces acting on a work-piece

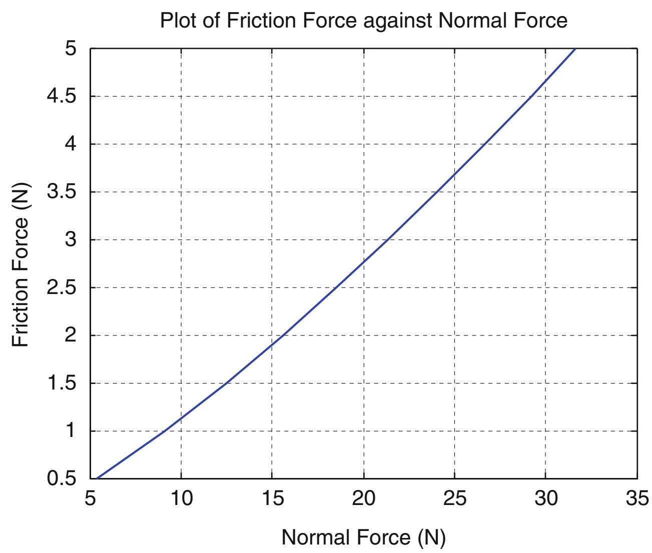

Fig. 5 Plot of friction force against the normal force

Similar analysis was done for loads from 1 N to 10 N at increments of 1 N and the plot of the friction force against the normal force is shown in Fig. 5.

The slope of the approximately linear curve obtained gives the coefficient of static friction between the work-piece and the rubber gripping pads which is calculated to be approximately 0.17.

Conclusion

The FlexiForce force sensor was used to successfully grip work-pieces of various masses up to 0.5 kg which is the maximum payload of the pick-and-place robot. This was achieved by manually specifying the gripping force in the test codes of the microcontroller. However, during fully autonomous operation, the system is currently unequipped to determine the weight of the work-pieces. As such, gripping is carried out with view of the maximum payload. A future goal is to make this system more intelligent whereby it can determine the weight of work-pieces itself and then apply the corresponding gripping force. Also, while rigid work-pieces were used in this experiment, further work needs to be done to see the performance of this sensor when manipulating delicate objects.

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Analyzing Operating Systems' Behavior to Crafted Packets

Thusith Abeykoon, Kasun Abeykoon, and Tirthankar Ghosh

Abstract

Operating Systems are vulnerable to malicious packet injection because of their inherent design and implementation flaws. TCP/IP stacks in different operating systems are especially vulnerable to this. Using crafted packets, we can analyze how each operating system responds to malicious packet injection. The main goal of this study is to analyze behavior of different operating systems to specially crafted packets. In this experiment, we crafted four types of packets: TCP SYN packets with data, packets with IP options, overlapping fragments, and tiny fragments. We use "Scapy" [1], a powerful packet crafting tool using Python to craft packets with customized headers and payloads. Results indicated that Windows and Linux behaved differently to these packets. Windows showed more vulnerability when receiving data in SYN packets, while Linux responded to packet with IP options. Both systems also handled overlapping fragments differently.

Keywords

Packet manipulation • Operating system behavior

Introduction

TCP protocol has some serious design flaws as per security is concerned. RFC 793 [2] does not prevent data being transported on a connection request packet. However, this is not the normal TCP protocol operation. If data is transported on a connection request packet, it is left on to the implementation of the TCP/IP stack to craft a response. However, the vulnerability can be exploited to port malicious code to a server.

IP is not free from vulnerable implementation either. IP options are one such grey area. RFC 791 [3] states that "the Options provide for control functions needed or useful in some situations but unnecessary for the most common communications". One common practice to mitigate against unwanted IP packets with options is to configure the border firewall to block them. However, options should be allowed in internal communications. Operating systems' behaviors to respond to packets with options are worth investigation.

IP fragmentation comes with its own flaws. The protocol fails to specify how the stack will handle overlapping and duplicate fragments, leaving it up to the implementation details to craft a response. Moreover, RFC 791 [3] states that all hosts must accept packets with minimum 68 bytes. This implies that a legitimate fragment can be crafted with 60 bytes of IP header, and 8 bytes of payload. This will result in the first 8 bytes of TCP header in the first fragment with the remaining going to the next one. Investigating response to such fragments will be crucial to understand the behavior of different systems.

In order to address these questions, we have conducted a series of experiments to investigate how different operating systems respond to these crafted packets. This paper summarizes the results.

The rest of the paper is organized as follows. Section "Design and Experimentation" discusses design of the

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_14,

Table 1 Seelction of target operating systems

Operating system	Version (32bit)	Kernel version	Installed software
Windows server	2003 R2	5.2.3790	Default install Apache Wireshark TFTP server
Redhat Enterprise Linux	5.4	2.6.18	Default install Apache Wireshark
Windows XP	SP2	5.1.2600	Default install Apache Wireshark TFTP server
Ubuntu desktop	10.04	2.6.38-11	Default install Apache Wireshark

attacks using packet crafter, followed by detailed discussion on the results in the third section. Finally, the fourth section concludes the paper.

Design and Experimentation

Design of the Attack Using Packet Crafter

We selected various Operation Systems (OS) and studied their response to crafted packets for the above four attacks. The table below summarizes the OSs used (Table 1).

We started with crafting packets to transport data on a TCP connection request. We used *sendpfast* command in Scapy to send SYN packets because it uses *Tcpreplay* to send packets faster.

```
sendpfast(Ether()/IP(src=RandIP(),
dst="intentionally   deleted",   flags=2,
ttl=32) / TCP(sport=(100,10000),dport=445,
flags="S", seq=100)/("X"*1400),loop=1000)
```

where:
RandIP(): Function in Scapy to generate random IPs.
flags = 2: Set Do not fragment bit in IP header.
sport = (100, 10,000): Send packets for TCP Source port range 100 to 10,000 for a IP address.
loop = 1,000: To run entire function as a loop for 1,000 times.
("X"*1,400): Send set of X values as data.

Our next experiment was to craft packets with IP options. In our test we used two IP options; Record Route, and Timestamp. We selected Record Route and Timestamp because those are two common IP options used by attackers. We disabled all host-based firewalls to identify the behaviors of IP stack with IP options. The following command was used for Record Route option:

```
p=IP(dst='intentionally
deleted',options=IPOption('\x07\x23\x08\x0
1\x02\x03\x04\x00\x00\x00\x00\x00\x00\x00\
x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x0
0\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\
x00'))/TCP()
```

where:
x07—Type: Record Route
x23—Length of the option field in Bytes
x08—Pointer shows next area to store IP address in Bytes
\x01\x02\x03\x04—Hex representation of bogus IP address 1.2.3.4

For the timestamp option, we used the following command:

```
p=IP(dst=' intentionally
deleted',options=IPOption('\x44\x0C\x05\x0
1\x00\x00\x00\x00\x00\x00\x00\x00'))/TCP()
```

where:
x44—Type: Timestamp
x0C—Option length in Bytes
x05—pointer for the next time value
x01—flag = 1:Timestamp contains IP address and Time

Our next experiment was to craft overlapping fragments, and study the response. We created a Python script which used six fragments to analyze the behavior of the Operating Systems when they received IP packets with same offset. In this script, checksum value should be changed in accordance to packet sequence and Operating System.

In Fig. 1 below, IP fragments three and four had the same offset (frag = 4). Responses were studied to analyze which fragments were dropped.

Lastly, we created tiny fragments to investigate the behaviors against them. A single IP packet was fragmented to size of 8 bytes, thus creating three fragments.

```
ip=IP(src="intentionally deleted", dst="
intentionally deleted ", flags=0, ttl=32)
tcp=TCP(sport=50000, dport=80, flags="S",
seq=100)
send(fragment(ip/tcp,fragsize=8))
```

We used "*fragment()*" function in Scapy to create fragments and *fragsize* parameter to set fragment size to 8 bytes.

Discussion of Results

Results from Experimentation with Transporting Data in SYN Packet

Using the script discussed in the previous section, we sent around 9 million packets within 224.23 s (around 40,000 packets per second).

```
#!/usr/bin/python
from scapy.all import *

vic = 'intentionally deleted'
frag0 = 'Receved '
frag1 = 'Fragmnt1'
frag2 = '_Fragmt2'
frag3 = '_Fragmt3'
frag4 = '_Fragmt4'
frag5 = '_Fragmt5'
ip=IP(dst=vic,proto=1,id=10101,flags=1)

icmp=ICMP(type=8,code=0,chksum=0xd65b)

pkt=ip/icmp/frag0
send(pkt)
ip=IP(dst=vic,proto=1,id=10101,flags=1,frag=2)
pkt=ip/frag1
send(pkt)
ip=IP(dst=vic,proto=1,id=10101,flags=1,frag=3)
pkt=ip/frag2
send(pkt)
ip=IP(dst=vic,proto=1,id=10101,flags=1,frag=4)
pkt=ip/frag3
send(pkt)
ip=IP(dst=vic,proto=1,id=10101,flags=1,frag=4)
pkt=ip/frag4
send(pkt)
ip=IP(dst=vic,proto=1,id=10101,flags=0,frag=5)
pkt=ip/frag5
send(pkt)
```

Fig. 1 Python script to craft overlapping fragments

Windows XP

We used Windows Task Manager to observe the behavior from the attack. During the attack, CPU usage went up to100 % and network usage went up to 48 % in 1 Gbps connection.

Windows Server 2003

We followed the same steps as in Windows XP to observe the behavior. During the attack, CPU usage in Windows Server 2003 went to 100 % and machine froze with time. Network usage went up to 48 % in 1 Gbps connection.

Ubuntu/Redhat Linux

In Ubuntu and Redhat linux, we followed a different method because there are no open TCP ports in default installations. We enabled port 80 to direct the attack. During the attack only few peaks in CPU usage was observed.

From the above results, we can conclude that Windows XP and Server 2003 are more vulnerable to data in SYN packet attack when compared to Ubuntu and Redhat Linux Operating Systems.

Results From Experimentation With IP Options

After analyzing reply packets, following behaviors were observed from each operating system for IP options.

Record Route Option

Windows XP

Windows XP did not add any data to the Record Route reply packet. Additionally it removed the IP address which we added to the packet.

Windows Server 2003

Windows Server 2003 acted the same way as Windows XP, it removed the IP address from the packet.

Ubuntu

The Ubuntu machine responded to Record Route packets with adding its own IP address when replying.

Redhat Linux

Redhat Linux also added its own IP address as next hop IP when replying to Record Route.

Timestamp Option

Windows XP

Windows XP did not add any data when replying to Timestamp option and it replied with the unchanged option field.

Windows Server 2003

Similar to Windows XP, Windows Server 2003 did not add any data to the reply packet.

Ubuntu

In contrast to Windows systems, Ubuntu added its own IP address and Timestamp to the replying Timestamp packet.

Redhat Linux

Redhat also added its own IP address and Timestamp to the replying Timestamp packet.

Above results clearly indicate how each operating system behaved when it received packet with Record Route and Timestamp options. Even without any default operating system firewalls, Windows XP and Windows Server 2003 did not reply to any packets with Record Route and Timestamp options. In contrast, Ubuntu and Redhat Linux replied to packets with Record Route and Timestamp options with their respective IP addresses and Timestamps.

Results from Experimentation with Overlapping Fragments

We sent six fragments to each operating system to analyze the behavior when they received IP packets with same offset.

After analyzing the received packets, it was noticed that windows and Linux operating systems handled packets with same offset in two different ways. There was no difference in output taken from two windows versions, and also same for two Linux versions.

Windows XP/Server 2003

Using scapy we sent ICMP echo request packet with six data fragments to the windows machines. ICMP echo reply packets were received showing that the windows systems dropped the second packet having the same offset.

Ubuntu/Redhat

After sending ICMP echo request packets in six fragments, and capturing the replies, it was found that the Linux systems dropped the first packet having the same offset.

Finally, the experiment was conducted by sending fragments with offsets 1 through 5. The results showed that all operating systems dropped the fragment with offset 1. This was probably to counter tiny fragment attack [4]. Staring from the fragment with offset 2, operating systems started behaving differently. Windows dropped the second fragment of the two overlapping fragments, while Linux dropped the first.

Results from Experimentation with Tiny Fragments

Windows XP/Windows Server 2003

We used Wireshark and *netstat* output as well as Windows firewall logs to observe the results. Wireshark output showed there were three fragments received, but *netstat* output didn't show any incoming connections in SYN_RECV state. For further observation, we checked Windows firewall logs and found dropped connection, but the logs did not show drops for all three fragments. There was no feature to block SYN flag or fragments in windows firewall. Therefore we can assume that Windows firewall reassembled the packet in buffer and firewall dropped the connection due to bad header length.

Ubuntu/Redhat Linux

To check in Ubuntu/Redhat linux, we enabled *iptables* firewall and set parameter " –f " with " ! " symbol to check whether the first fragment contained the TCP SYN flag in connection.

Iptables -A INPUT -p tcp ! -f –tcp-flags SYN, ACK SYN –j DROP

In Ubuntu/Redhat linux, *netstat* output did not show any new connections. We set *iptables* firewall rule without "!" symbol in "–f" option. This would ignore the first fragment and start to check from second fragment whether TCP SYN flag was set or not.

Iptables -A INPUT -p tcp -f –tcp-flags SYN, ACK SYN –j DROP

We started to send the packets again, and *netstat* output showed that there was a connection starting from our attacking machine.

As we were sending SYN flag in the second fragment during the second attempt, the *iptables* rule should have blocked the connection. But we could see that connection establishment was started. From the previous setting, we could see that connection was blocked. Therefore we can assume that Ubuntu also reassembled the packet in buffer and sent it as a single packet to *iptables*.

Conclusion and Future Work

In this paper we have investigated response behavior of various operating systems to crafted packets. We specifically studied behavior of Windows XP, Sever 2003, Red Hat Enterprise, and Ubuntu Desktop edition in responding to three different types of crafted packets: transporting data in SYN, packets with IP options, and overlapping fragments. We found that Windows systems showed more vulnerable behavior to data with SYN packets, while Linux systems responded to packets with IP options (we used Record Route and Timestamp options). The two operating systems also behaved significantly differently when dealing with overlapping fragments; Windows preferred the former fragment, while Linux preferred the later one.

More investigations need to be conducted to study response behaviors of systems to other crafted packets. Special focus should be given to how operating systems behave to buffer overflow using IP fragments. In addition, it will be interesting to observe how firewalls behave to tiny fragment attacks. Our investigation with tiny fragment attack was very preliminary, and there is a need for further investigation.

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An Access Control Model for a Grid Environment Employing Security-as-a-Service Approach

E.K. Olatunji, M.O. Adigun, and E. Jembere

Abstract

There is a continuous effort at addressing security challenges of large scale service oriented computing (SOC) infrastructures like grids. A lot of research efforts towards development of authentication and authorization models for grid systems have been made because existing grid security solutions do not satisfy some desirable access control requirements of distributed services; such as support for multiple security policies. However, most of these security models are domain and/or application specific. Domain/application-specific approach to providing security solution is a duplication of effort, which also increases the cost of developing and maintaining applications. This paper presents the design of an access control model for grid-based system that employs security as a service (SecaaS) approach. By SecaaS approach, each atomic access control function (such as authentication, authorization) will be provided as a reusable service that can be published and subscribed to by different grid entities. In this approach, each admin domain will no longer need to have its own domain-specific access control logic built into it. Whenever an access control service is required the domain administrator subscribes to this service from SecaaS. This approach has a number of benefits, including making changes to security policies dynamically on the fly.

Keywords

Access Control • Administrative Domain • Grid Computing • Security • Service provider

Introduction

Grid computing enables the use and pooling of computers and data resources to solve problems that are far too big and complex for any single super computer to complete within a reasonable time frame. The goal of grid computing is the provision of flexible, secure, and coordinated resources sharing among dynamic collections of individuals, institution and resources distributed over heterogeneous wide area network.

This computing paradigm involves an evolving set of open standards for web services and interfaces that make services or computing resources available on the internet [1]. Application areas and examples of grid projects are detailed in [2] and [3].

Security, however, is a big challenge in a large scale distributed system like grid, as it involves the federation of multiple heterogeneous, geographically dispersed autonomous administrative domains [4]. The peculiar characteristic of a grid environment presents unique security challenges that are not addressed by traditional client-server distributed environments [5, 6]. This security challenge has been attributed to be one of the biggest obstacle to wide scale adoption of grid computing [7], despite its many benefits.

The first and more notable security architecture for grids was the one proposed by Foster et al. as cited in [8].

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_15,

The architecture addresses several unique grid security requirements. Security requirements within the grid environment are driven by the need to support scalable, dynamic, and distributed Virtual organization (VO), which is a collection of diverse and distributed individuals and organization that seek to share and use diverse resources in a coordinated fashion.

The core security services of SOC systems like grids, including authentication, secure communication, authorization and auditing, should be provided on an end-to-end basis. That is data, services and other resources must be protected over the entire path of requests and responses as they travel through the system [9]. Additional and peculiar securities features that need to be supported by security infrastructure for grid and web services, such as single sign on, multiple security policies, etc., are detailed in [6] and [10].

A number of grid security infrastructures (such as GSI, CRISS, PERMIS, etc.) have been developed because existing security solutions for client-server distributed systems do not address the peculiar security challenges of a grid environment [5, 6]. According to some scholars, these grid security solutions do not adequately satisfy some desirable access control requirements of distributed web services, such as support for multiple security policies, support for fine grained access, etc. [4, 6, 10, 11].

This inadequacy of existing Grid security infrastructures has motivated the proposal, design and/or implementation of a number of other, most often domain/application-specific, authentication (aN) and authorization (aZ) models and infrastructures for grid systems by [4, 6, 10–12]. The problem with this approach of providing domain/application—specific security solution is that of duplication of effort, as well as increase in the cost of developing and maintaining applications. This problem was also noted by [13]. One of the aims of this research effort is to employ an alternative approach to providing access control solutions that is not domain or application specific for a grid environment.

A better method at addressing security issues in grid system, we believe, will be to employ SecaaS approach for satisfying access control requirements of distributed services in a grid environment. By this approach, each atomic security function will be provided as a reusable service to be published and can be subscribed to by different grid entities. In this approach, each admin domain will no longer need to have its own domain-specific access control logic built into it Whenever an access control service is needed the domain administrator subscribes to this service from SecaaS.

Our proposed security model will be constructed to be independent of middleware and service providers/resources owner unlike in the existing models. The model also aims at providing multiple mechanisms for aN and aZ; thus the grid entities will have the priviledge of specifying their preferred mechanism for aZ and aN. Our proposed solution will also be web services security standard compliant.

The SecaaS approach has the following potential benefits:

- Great reduction in the cost of developing and maintaining applications as well as enabling developers to concentrate on the logic of applications
- Developing and maintaining security services at very few points
- Changing of security policies dynamically on the fly at no extra cost
- Flexibility for Service Providers in making use of their preferred access control mechanisms as multiple mechanisms will be supported
- Scalability
- Support for fine—grained access control
- Support for multiple security policies
- Being standard-based

The remaining part of this paper is organized as follows: second section provides a brief review of related works, while components of a typical grid environment are described in the third section. A brief description of existing approach to providing access control in a grid environment is given in the fourth section. The design and description of our proposed SecaaS model are the focus of the fifth section. Finally, the sixth section concludes the paper and gives direction for future work.

Related Work

Review of literatures revealed that a lot of effort has been made in attempt to address security challenges of large scale distributed system like grid. Jie et al. [5] and Singh, Singh & Kaur [4] carried out a review of a number of projects and models that have been carried out in an effort to address authorization and access control related issues in one form or the other. Among these projects are CARDEA, CRISIS, Gridship and Legion [4]. Others include GridshipPERMIS, and Internet2Shiboleth [5].

Security infrastructures/technologies like Globus GSI, Kerberos and Athens [5] are common authentication infrastructures for grid systems. However, each of them makes use of only one mechanism for authentication; none has support for multiple authentication mechanisms. Kerberos is not explicit in provision of single sign-on feature, while Athens has no support for delegation. Support for these features are desirable in grid security infrastructures [4, 5]. In the same vein, authorization infrastructures like CAS [5], VOMS [4], PERMIS and Akenti [5] have provision for only one authorization model, using either user name, a user group, a user role, user attribute, etc. Ideally, service providers only need to determine what type of access to grant to different categories of users and then leave the authorization infrastructure to enforce the policies [5].

A number of researchers, including [4, 10, 11], have also observed some of the inadequacies of many of the existing grid security infrastructures to satisfy some authentication and access requirements of distributed services and have been motivated to propose, design and implement other authentication and/or authorization frameworks and models for distributed services.

For instance, Squicciarini et al. [12] proposed and developed an authentication (aN) framework which supports multiple aN mechanisms combined through aN policies and on the association of aN requirements with the protected resources. They were motivated by the fact that protected resources of a system may require different aN strengths for different users wishing to access them; and that the existing approaches to 'continuous aN' were not expressive enough to support fine-grained aN policies. Their framework does not take care of grid aN requirement such as mutual authentication. Furthermore, it is to be weaved in to the application and thus it is application specific. In addition, aN function is not being offered as a service.

An authorization (aZ) framework that can support multiple policies in the Globus Tookit 4 was designed and constructed by [11]. This was in recognition of the fact that aZ mechanisms in Grid computing platform needs to support multiple security policies and have the flexibility to support dynamic change in security policies. These features are not present in the existing aZ frameworks for grid System.

A policy–based aZ and access control model for a grid environment was designed and implemented by [4]. This was attempted because, according to them, existing traditional client/server based distributed system did not address the peculiar aZ and access control challenge of a large service-oriented computing like grid with many different domains. The model however does not provide for context aware access control mechanism which is also a desirable features of a large scale distributed system. Unlike our model, their aZ model will have to be incorporated in the system of a service provider of a particular domain.

Ekabua & Adigun [10] designed a GUISET-driven aZ framework because, according to them, existing aZ frameworks for grid systems are not suitable or applicable to GUISET—a grid based infrastructure. Their framework was specifically designed for GUISET environment. Our proposed approach of offering security solution in grid environment will not require each application or domain to have its own security subsystem.

The following are note worthy in the works of all these reviewed scholars. They were motivated to carry out their work because existing security solutions for grid are not adequate in providing some desirable access control requirements for web services in a Grid environment. Secondly, the proposed and/or prototyped aZ framework are application or domain specific. Domain-specific approach to providing security solution results in two key related problems: replication of effort as well as increase in application development and maintenance cost. These problems were also noted by [13].

Our intended method of addressing these problems is by employing 'security as a service' (SecaaS) approach in which each key access control security functions will be provided as a service that would be published and can be subscribed to by any grid entity. Service providers will no longer need to bother themselves with implementing the logic of their own detail domain/application specific security solutions for access control. Our proposed security model will be constructed to be independent of middleware and service providers/resources owner unlike in the existing models.

Components of the System

An access control security system can be defined as a system that grants or denies access to protected resources or services (R/S) based on the access rights/privileges of the requesters with respect to the security policies of the owner of R/S. In order to make the system model being presented understood, the following are some of the components or entities that interact together in the system.

a. **Service Requester** (**SR**), (which is more commonly referred to as Subject (SU)), is an entity that wants to make access to a protected R/S in the system. This can be a grid user, a service or any other entity acting on the behalf of a user/service. A SR is denoted by a *rounded rectangle*.
b. **Service** (**S**) is a piece of code that provides some functionality and can be appropriately accessed by SRs. Services are published in the environment and can be discovered and subscribed to by SRs. Service is represented by a *triangle*.
c. **Resource** (**R**) is an object that can be appropriately accessed and used by SRs. Appropriately used in the sense that SR must need to comply with the policies (rules and regulations) guiding the use of both services and resources. Typical resources include CPU, storage, data, applications, scientific instruments, etc. Resources are accessed by SR through services. Thus a resource is also a service in this sense. Resources are denoted by a *square*.
d. **Security Service Policy** (**SeP**) is a set of rules and regulations associated with the use of a service (or a resource). A SR must comply with the policy before access is granted to the service. SeP is represented by an octagon.
e. **Administrative Domain** (**AD**). This is the collection of Service Requesters, Service Providers (SP), Services and

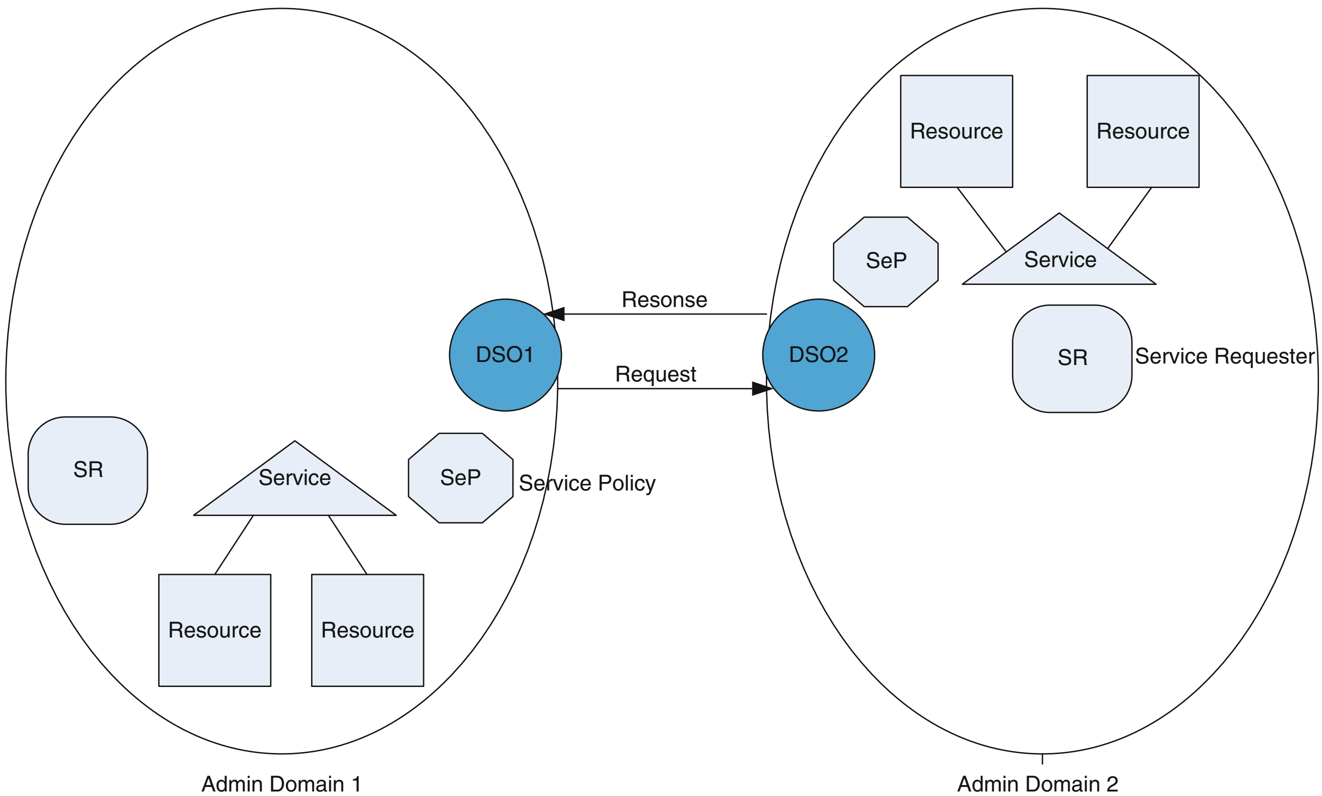

Fig. 1 A grid system consisting of two admin domains together with some of their entities (A SR from AD1 requests for service from AD2)

Resources that are bound by a common but unique domain policy (DP). Domain policy is a set of rules and regulations that an entity must abide with in order to belong to the AD. An AD is depicted by a *big oval* (egg-like shape) or *ellipse*.

f. **Service Providers** (**SP**) are also members of a particular AD that own services and resources which are exposed within a grid environment. They provide service by publishing their services for SRs to discover and subscribe to them. At any time in a grid environment, a SP can transit to a SR as the need arises.

g. **Policy Database** (**PD**). This is a repository for temporary storage of all relevant policies provided by domain security officer (DSO) when requesting for any of the security services from SecaaS. The policies are the one that are applicable to SR and services/resources. In non-SecaaS based security system, all the policies of an AD are stored almost statically in the policy database for the policies.

h. **Domain Security officer** (**DSO**). Each administrative domain has an administrator or a security officer who carries out necessary access control checks for requested R/S by SRs. Access control check is carried out even if an SR is making access to R/S in its home domain. Access request for R/S outside one's home domain is passed through the home DSO to the DSO of the target admin domain. In our proposed model, DSOs subscribe to access control services of SecaaS.

In a typical grid environment, depicted in Fig. 1, these components/entities interact with one another in a complex and dynamic manner. Figure 1 shows a grid system consisting of two admin domains and some of their entities. In the diagram/figure, Service Requester, Services, and Resources are respectively represented by rounded rectangle, triangle and a square while SeP and AD are denoted by an octagon and an oval shape respectively.

As can be seen in Fig. 1, every request for a R/S goes through the DSO who carries out necessary security/access control checks. In the proposed model, DSO carries out access control checks by subscribing to the services of SecaaS.

The Existing Approach of Providing Security in Grid Systems

In the existing approach of providing security solution, each AD has an entity equivalent of DSO, who carries out necessary access control checks for all requested R/S by SRs. Request to access R/S within one's domain is passed through the home domain's DSO. For instance, both AD1 and AD2 in Fig. 1 have their own domain-specific security infrastructure. Any SR from AD1 attempting to access R/S from its home domain would have to be checked for access rights to his desired R/S. However, if a SR from AD1, for example, wants to access R/S in AD2, the request is passed through RS′ home DSO, the access rights of RS′ home domain (AD1) will be vetted by AD2. Of course, the access rights of a SR from AD1 is necessarily a subset of the access rights granted by AD2 to SR/Subject of AD1. Access to the requested R/S is granted if and only if SR from AD1 complies with the security policies associated with the requested R/S in AD2; otherwise, access is denied.

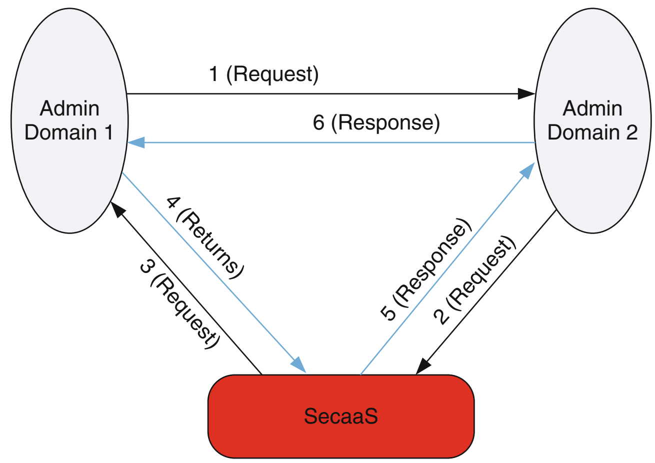

Fig. 2 Request-Response between two Admin Domains (with SecaaS). *Notes* 1. Request for Resource/Service from Admin Domain1. 2. Request for a service from SecaaS by Admin Domain2. 3. Request for security tokens of the requester of Resource/Service. 4. Security tokens of Requester returned to SecaaS. 5. Response from SecaaS Admin Domain2. 6. Response from Admin Domain2 to Admin Domain1

Description of SecaaS Approach

Describing the SecaaS Model

In the proposed SecaaS approach, each AD does not have its own domain-specific security (access control) logic built into it, unlike in the existing approaches. Although each AD still has an entity that serves as DSO. For any domain to carry out access control checks, the domain subscribes for access control services from SeccaS, which performs appropriate access control checks (e.g., aN or aZ checks) for the domain, and returns a 'Grant' or 'Deny' access response.

For SecaaS to carry out requested security/access control checks, the security policies associated with the requested R/S are part of the parameters to be supplied by the domain requesting for security/access control services. These policies are evaluated and a response of 'Grant' or 'Deny' access is returned to the domain requesting for security service. If policy evaluation results in a 'grant access', access will be granted to the SR of the R/S, otherwise access is denied.

All request for R/S goes through the security officer of each domain (DSO). If the SR and requested R/S belong to the same domain, their DSO requests for security service from SecaaS, even if SecaaS provider also belongs to the same domain. However, if the requester and the requested R/S belong to different ADs, the DSO of SR will send request for R/S to the domain of the requested R/S. The DSO of the requested R/S will intersect this request and then request for appropriate security/access control services from SecaaS. Figure 2 is a schematic diagram of the proposed SecaaS approach. It shows the flow of request and response for R/S between two ADs.

In this Fig. 2, when a SR from AD1 through its DSO, for example, requests for R/S from AD2, the DSO of AD2 intersects this request, and carries out access control checks on the SR by subscribing to the services of SecaaS. When SecaaS receives a request for acess control checks on a SR from AD2, it will request for the security tokens (e.g. authentication tokens) of the SR from the SR's AD (i.e., AD1). SecaaS will then carry out necessary access control checks by evaluating the request against the security policies associated with the requested R/S and then return a 'Grant' or 'Deny' access response to AD2. Based on the security decision received from SecaaS, AD2 will either grant or deny access to the requested R/S. Section 'Description of Components of SecaaS Model' is a brief description of relevant components of our SecaaS architecture.

In addition to eliminating the need for every administrative domain to have its own in-built access control logic, the SecaaS approach of providing access control to protected R/S in a grid environment facilitates dynamically making changes to access control policies on the fly.

Description of Components of SecaaS Model

The SecaaS model as was initially proposed by Bertino et al. [13] is as shown in Fig. 3. However, the model has not yet been investigated nor implemented.

In the reference architecture shown in Fig. 3, it is assumed that the process of providing access control to a protected resource and/or services (R/S) encompasses and begins with identification, followed by authentication and then by authorization.

According to the principles of SOA, each component of SecaaS is a service. Furthermore, by following the XACML model of OASIS [14] each component in SecaaS is made up of two distinct elements, the PDP and the PEP; which are

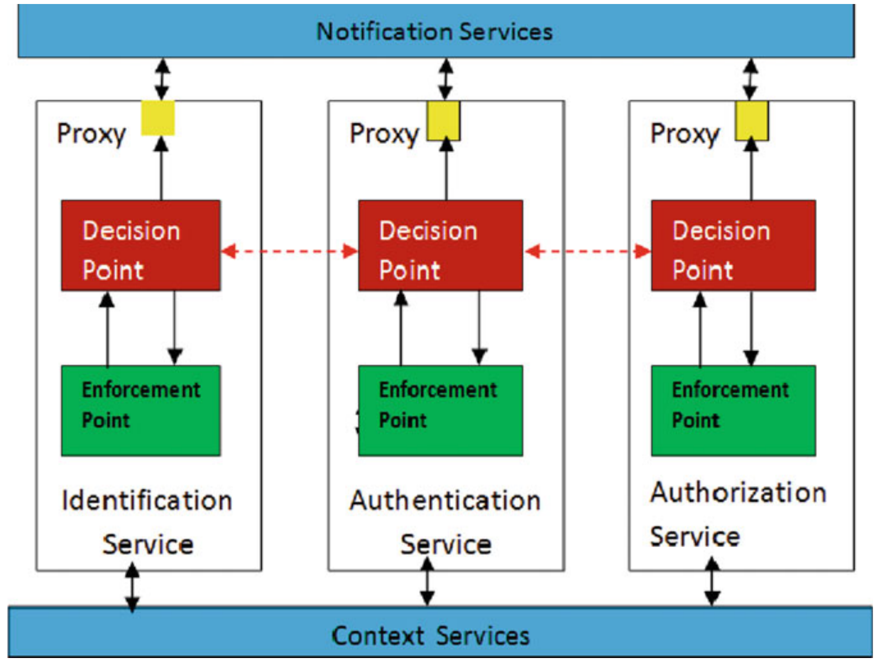

Fig. 3 SecaaS reference model [13]

driven by the relevant security service policies. According to the XACML model, separating the decision point from enforcement point makes it easy to update decision criteria on the fly when the governing policies changes.

The policy decision point (PDP) in the SecaaS reference architecture (see Fig. 3) is the point at which security decisions are made based on the security policies associated with protected resources/services (R/S). Such a decision point for a given security service (e.g. authentication service) may need to interact with another security service's decision point in order to reach a security decision. The policy enforcement point (PEP) is the point where access is granted or denied based on access decisions received from PDP.

The notification Service is included in SecaaS framework so that it can help in maintaining a coherent state of security information. Particularly, it is meant to notify any of the security services in SecaaS of any event relevant to it. For example, in healthcare services, when a Medical Doctor resigns, an identity event can be generated. The context service component is to help keep track of and make available relevant shared contextual information among the security services.

Procedure of Access Request for Resources/ Services in a Typical Grid Environment Using SecaaS Approach

In this section, a scenario in which a requester in one AD (e.g. AD1) is requesting access request to R/S in another AD (e.g. AD2) is described. Figure 4 shows this scenario. The procedure for requesting for R/S in this scenario is as follows:

1. A SR from AD1 makes access request through its home DSO (DSO1) for a R/S in AD2.
2. DSO1 Passes the request to AD2. The request is intersected by DSO2.
3. DSO2 subscribes for access control service from SecaaS in order to ascertain the access rights/priviledges of the SR
4. SecaaS requests AD1 to send the security (e.g. authentication) tokens of SR
5. Security tokens of SR is sent by AD1 to SecaaS.
6. SecaaS engine retrieves security policies associated with the R/S, and evaluate these against the request.
7. Security decisions (grant or deny access) made by SecaaS is conveyed to the security officer of AD2 (DSO2).
8. DSO2 grants access request to the R/S concerned because security decision provided by SecaaS is favourable.
9. DSO2 conveys 'Access denied' information to the DSO because security decision made by SecaaS is not favourable.
10. The 'Access Denied' information provided by DSO2 is forwarded to the SR by its DSO (DSO1).

Procedure for Requesting a Typical SecaaS Service

Figure 5 is a model showing request and response for a typical security service (e.g. authentication or authorization). The procedure, as schematically shown in Fig. 5, is as follows:

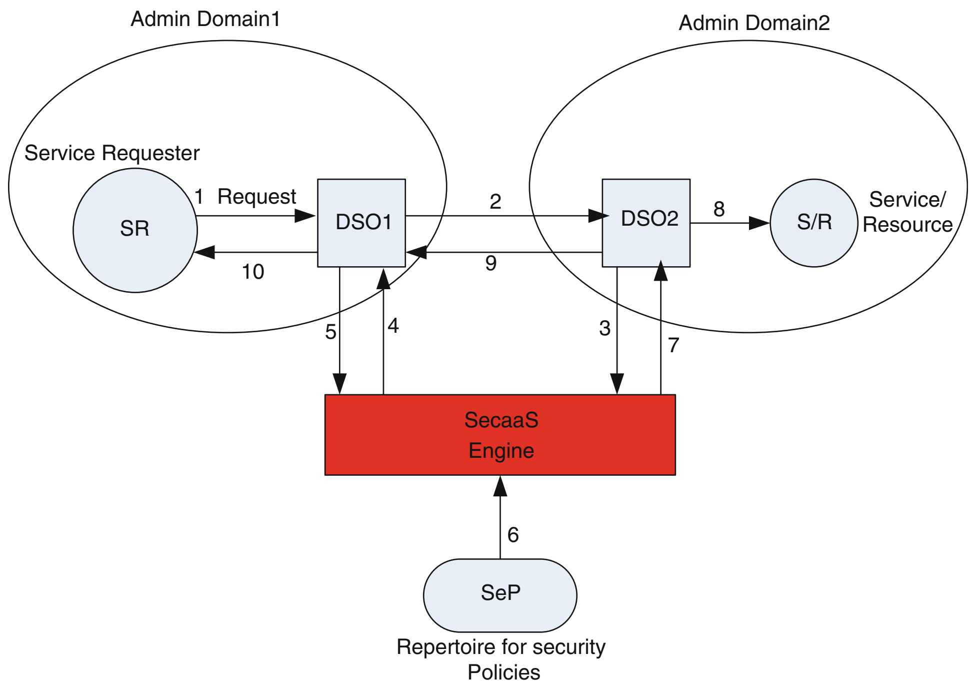

Fig. 4 A schematic diagram showing request for access control services when both the SR and the R/S belong to different Ads

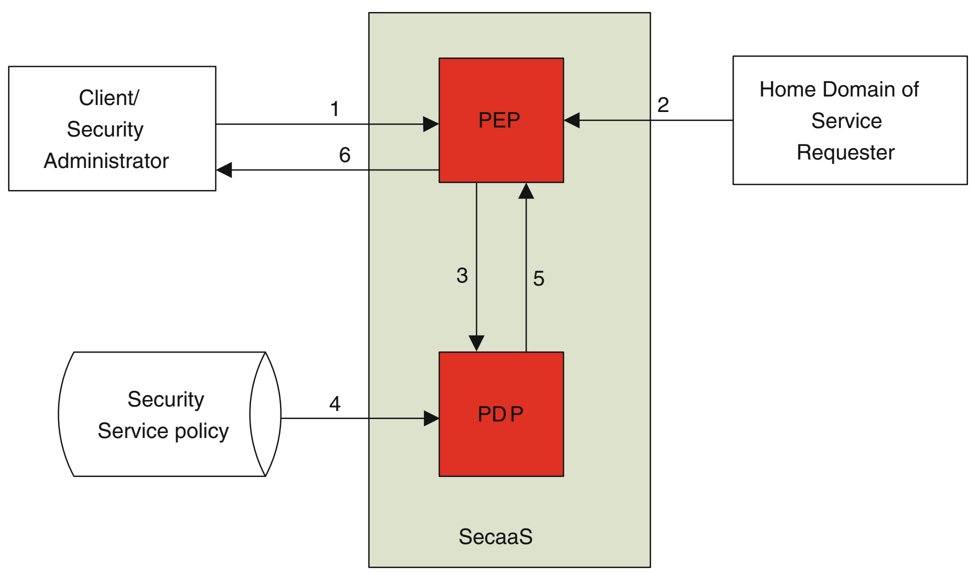

Fig. 5 Request for a typical access control service (e.g. Authorization service)

1. A client request for aZ service from SecaaS (the client, in this case, is the entity requesting for security service; typically it is the DSO). The request is intercepted by PEP of SecaaS.
2. PEP obtains the security token (e.g. aZ privileges) of SR from SR's home domain
3. PEP constructs necessary query and contacts PDP for access decision-making.
4. PDP retrieves appropriate aZ policies associated with the requested R/S and as sent to it by the client and evaluates the request against the policy.
5. PDP sends the result (Grant or Deny access) of aZ policy evaluation to PEP for necessary action. (All that PEP does here is to forward security service decision on the access request to the client).
6. PEP returns access decision (Grant or deny access) to the client (i.e. the DSA that requests for security service)

Note: The security service policy 'database' (a temporary repertoire for security services policies) with SecaaS in Fig. 5 is not static. It varies with each request for security service.

Conclusion and Future Work

A Security model that employs SecaaS approach in addressing security challenges of a grid environment has been presented in this paper. This model is proposed because the solutions offered at addressing the inadequacies of the existing grid infrastructures in satisfying some desirable access control requirements of distributed services result in replication of effort as well as increase in the cost of developing and maintaining applications.

In the SecaaS approach, each atomic access control function/service, such as authentication, authorization, etc. will be provided as re-useable services that can be exposed and then subscribed to by different grid entities. In this security model, each AD in a grid environment will no longer need to have its own domain-specific access control (security) logic built in to it. Whenever a security service is required, the domain subscribes to this service from SecaaS. The potential benefits of employing SecaaS approach at providing security solution for a grid system are as high-lighted in section one.

The next stage in this work is to carry out a prototype implementation of our SecaaS model. We intend to carry out the implementation in .NET environment with the support of WSE 3.0 toolkit, and WSRF. WSE 3.0 has support for web service security specification like ws-security, and ws-secureConversation. Ws-security [13] is the facto standard for security message in the web. It enables one to selectively encrypt or sign different part of single SOAP message for different recipients. Ws-secureConversation [13] was designed to provide secure communication for multiple SOAP messages. WSRF is an OASIS standard, generic and open framework for modelling and accessing stateful resources by using web services. It provides specification for making web service to become stateful [3]. Stateful web services are generally required by grid applications.

The prototype implementation will begin with two ADs, each having 2-5 service providers (SPs) which would provide R/S to other domains. Afterward, more ADs will be added, while also increasing the number of SPs in each domain. R/S will be exposed as (stateful) web services, with each R/S having its own set of security policies as provided by the domain Administrator. Policies associated with a R/S will be stored in a database within its domain in the XACML format.

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Comparison of Collaborative-Filtering Techniques for Small-Scale Student Performance Prediction Task

Štefan Pero and Tomáš Horváth

Abstract

Collaborative-filtering (CF) techniques were successfully used for student performance prediction, however the research was provided mainly on large and very sparse matrix representing (student, task, performance score) triples. This work investigates the usability of CF techniques in student performance prediction for small universities or courses with only a few of students. We compared several CF techniques on a real-world dataset collected at our university which is very small and not so sparse. The experiments show that in such cases the predictive accuracy of these models is not so good and we need to utilize more information about students or tasks.

Keywords

Recommender system • Matrix factorization • Predicting student performance

Introduction

Recommender systems (RS) are largely used nowadays not only in the e-commerce but also in e-learning. The main goal of a RS is to provide the user with items which the user is more likely to be interested in. Such items in case of e-learning represent study resources such as papers, books, hyperlinks, presentations, or even whole lectures or seminars. Collaborative-filtering (CF) is one of the most popular recommendation technique [6]. One of the advantages of CF is that it provides good recommendations even if only the *(user,item,feedback)* triples are known, thus, we can eliminate the costly gathering of—often sensitive—information about users and items.

Computer-aided tutoring systems allow students to solve some problems (exercises) with a various tools that can be useful for students and help automate some annoying tasks, provide some hints and feedback to the students. Such systems can profit from anticipating student performance (e.g. selecting the right combination of exercises, choosing an appropriate level of difficulty). The problem of student performance prediction means to predict the likely performance of a student for some exercises. Computer-aided tutoring systems also allow to collect a rich amount of additional informations about students behaviour (interaction with system and his past successes and failures) and about tasks (difficulty of task and success to solve).

Thai-Nghe et al. [7] and Toscher et al. [9] showed that recommendation techniques can be used to solve the student performance prediction problem such that users, items and feedbacks correspond to students, tasks and the success rate of the solution, respectively. They showed that matrix factorization (MF) techniques [4] achieve good prediction accuracy on a real-world, large-scale KDD Cup 2010 dataset[1] where the challenge was to predict how students will succeed in solving tasks. Even if the target attribute was binary, i.e. a student solves a task or fails, the probabilities of successful solutions were predicted.

The *(student,task,performance)* triples represented as a matrix in the KDD Cup 2010 data have three main

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[1] https://pslcdatashop.web.cmu.edu/KDDCup

T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_16,

Table 1 Programming algorithms complexity datasets

Dataset	#Students	#Tasks	#Instances
PAC-dataset	82	18	1,251

characteristics, namely that (1) the feedback is binary (1 for the successful solution and 0 for fail), and, the mentioned matrix is (2) large and (3) very sparse.[2]

It is known that CF (MF) techniques are suitable for large and very sparse matrices. However, smaller universities have not so many students, and thus, the input *(student, task,feedback)* matrix is indeed small. That is the case for the "Programming, Algorithms and Complexity (PAC)" course taught at our university, where the size of such matrix and its sparsity would be much smaller (see the Table 1) as in the above mentioned KDD Cup 2010 dataset. Moreover, the input matrix is not binary but contains grades in the range [0, 10] representing the amount of points the student achieved for the given task.

The question we investigate in this paper is the following: Are CF (MF) techniques usable for student performance prediction or task recommendation in the programming course at our university? We compare the predictive capabilities of several CF techniques in terms of the root mean squared error. A real-world dataset collected during the last two years from the PAC course taught at our university is used in our experiments.

Student Performance Prediction

Let $\mathcal{S}$ and $\mathcal{T}$ be the set of students and tasks, respectively, and $P \subset \mathbb{R}$ be the set of performance scores. A mapping p: $S \times T \rightarrow P$ which represents a performance *pst* of the student s achieved on the task t is explicitly defined by a set of recorded *student-task-performance score* triples (matrix)

$$D = \{(s,\ t,\ pst)½sö S,\ tö T,\ pstö P\} \qquad (1)$$

We usually split D into $D^{train}, D^{test} \subset D$ simulating students' past and future performance, respectively, such that $D^{train} \cap D^{test} = \emptyset$. The goal of student performance prediction is, given D^{train}, to find a mapping $\hat{p}$: $S \times T \rightarrow P$ such that

$$error(p,\ \hat{p}\ ) = \sum_{(s,t,p_{st}) \in D^{test}} (p_{st} \hat{p}_{\ st})^2 \qquad (2)$$

is minimal, where $\hat{p}_{st}$ is the predicted student performance score achieved on the task t by the student s.

[2] 2 99.8 % and 99.6 % sparsities for the two released samples in the KDD Cup 2010 data, denoted as "Algebra" and "Bridge".

Recommender Systems Techniques

One of the RS techniques is content-based filtering which creates a profile for each user w.r.t. attributes of items the given user has provided feedback for, i.e. liked or rated the item. Items which match the user profile are then recommended to the user. Content based strategies require gathering external information about products that might not be available to collect or its collection is costly.

An alternative to content-based filtering is the collaborative filtering approach which analyzes similarities between users and interdependencies between items to identify new user-item associations. The two primary areas of collaborative-filtering techniques are the neighborhoods methods and latent factor models. Neighborhoods methods are centering on computing relationships between users or, alternatively, items while Latent factor models map users and items to a common latent space which dimensions (called factors) represent implicit item characteristics and users' interests in these characteristics [4]. Items which are "close" to the user in the latent space are then recommended to her.

k-Nearest Neighbors

In this approach [3], each user is represented by a vector of performance scores on each task, i.e. a row in the matrix D defined in (1). Prediction of a performance score $\hat{p}_{\ st}$ of the student s for the task t are provided by the following principle: First, the set $N_t^{s,k}$ of those k most similar users to the user s which have been performed on the task t is created

$$N_t^{s,k} = \arg_{s'} \max \sum_{\substack{s' \in s',\, s' \neq s \\ s' \subseteq S_t,\, |s'| = k}} sim\left(s, s'\right) \qquad (3)$$

where $S_t = \{s \in S | \phi(s, t)$ is defined in $D\}$. $sim(s, s')$ is any suitable similarity measure, e.g. the pearson-correlation similarity. Then, the prediction $\hat{\phi}_{\ st}$ is computed in a mean-centered way as

$$\hat{p}_{\ st} = \overline{p}_s + \frac{\sum_{v \in \mathcal{N}_t^{s,k}} \ sim(s,v) \cdot (p_{vt} - \overline{p}_v)}{\sum_{v \in \mathcal{N}_t^{s,k}} |\ sim(s,v)|} \qquad (4)$$

where $\overline{p}_s$ denotes the average performance score of the student s computed over all of the performed tasks by her.

Matrix Factorization

The most successful realization of latent factor models are based on matrix factorization models [4] which map students and tasks to a joint latent factor space of some dimensionality. High correspondence between student and task factors leads to a recommendation. These models have become popular in recent years by combining good scalability with predictive accuracy.

The goal of matrix factorization techniques is to approximate the (sparse) matrix D of type $\mathbb{R}^{|\mathcal{S}|\times|\mathcal{T}|}$ as a product of two smaller matrices $W \in \mathbb{R}^{|\mathcal{S}\times K}$ and $H \in \mathbb{R}^{|\mathcal{T}\times K}$

$$D \approx W\, H^T, \tag{5}$$

where K is the number of latent factors representing some implicit characteristics of tasks and students' skills corresponding to these characteristics.

The performance score $\hat{p}_{st}$ of the student s for the task t is then predicted as

$$\hat{p}_{st} = \left(WH^T\right)_{st} = w_s h_t = \sum_{k=1}^{K} w_{sk} h_{tk} \tag{6}$$

where the vectors w_s, h_t denote the sth and tth rows in the matrices W and H, respectively, with w_{sk}, h_{tk} being the elements of these vectors which we call factors.

The main issue of this technique is how to find optimal parameters (elements of) W and H given a criterion such as the squared error introduced in the (2).

The most popular factorization technique used in the recommender systems community, exploits stochastic gradient descent optimalization [4] to find the parameters W and H by minimizing the following objective function

$$\sum_{pst \in D^{train}} \left(p_{st} - \hat{p}_{st}\right)^2 + \lambda\left(W^2 + H^2\right) \tag{7}$$

where $\hat{p}_{st}$ is defined as in (6) and λ is a regularization term to prevent so-called overfitting (i.e. when a model performs very well on the training data but poorly on the test data).

The Cold-Start Problem

The well-known cold-start problem arises when a new user or a new item arrives to the system. For such a user or item there are no factors computed yet and thus, we have to use some basic models for recommendation. On of these basic models is to predict the global average rating [μ in the (10)] for an item

$$\hat{p}_{st} = \mu = \frac{\sum_{(s,t,p_{st})} \in D^{train} p_{st}}{\left|D^{train}\right|} \tag{8}$$

An other simple recommendation model is the so-called student-task bias which predicts the ratings as follows

$$\hat{p}_{st} = b_{st} = \mu + b_s' + b_t'' \tag{9}$$

where μ is the global average as defined in (8), b_s' and b_t'' are so-called student and task biases expressing the deviation of student's performance from the average and the deviation of performances provided for the task from the average. In simple words, student bias expresses how good the student is while the task bias expresses how hard the task is.

Biased Matrix Factorization

To incorporate the student and task biases to matrix factorization, the prediction in (6) needs to be changed to

$$\hat{p}_{st} = \mu + b_s' + b_t'' + \sum_{k=1}^{K} w_{sk} h_{tk} \tag{10}$$

When using SGD (Stochastic Gradient Desctent) [4] for biased MF, besides W and H , three more parameters need to be optimized in (11), namely, the overall average μ and the vectors $b' \in \mathbb{R}^{|\mathcal{S}|}$ and $b'' \in \mathbb{R}^{|\mathcal{T}|}$ of students' and tasks' biases, respectively.

$$\sum_{pst \in D^{train}} \left(p_{st} - \hat{p}_{st}\right)^2 + \lambda\left(W^2 + H^2 + b'^2 + b''^2\right) \tag{11}$$

SVD++

A well-known factorization technique is the Singular Value Decomposition (SVD) which was used in information retrieval [1]. However, because of the sparsity of the matrix D we cannot use SVD directly, thus, we should either compute SVD only approximately [5] or fill the missing values by zeros but this latter way can distort the data considerably.

Koren introduced an SVD++ approach [3], in which also some implicit information can be used, such as, for example the fact that a student has performed/tried a given task at all. If the user can choose between more tasks to solve, she will try to solve that task which he prefers more. Thus, in addition to the performance score on a given task we know an implicit information that this task was also preferred by the user.

In SVD++, each student is associated with two sets of items: the set E_s contains items we have some explicit information for (e.g. a preference score), while the set I_s contains items we have some implicit information for (e.g. the student tried to solve the task).

The performance score $\hat{p}_{st}$ of the student s for the task t is then predicted as

$$\hat{p}_{st} = b_{st} + h_i^T \left(\frac{\sum_{i \in E_s} (p_{si} - b_{si}) x_i}{\sqrt{E_s}} + \frac{\sum_{i \in I_s} y_i}{\sqrt{I_s}} \right) \tag{12}$$

where b_{st} is the student-task bias as defined in (9). Each item is represented by three factors h, x, y and each user is represented through the items she prefers.

Experiments

Data and Settings

We have used the "labeled PAC-dataset"[3] , what contains more than 1 k *student-task-performance score* triples. The score scale is $V = \{0, 1, 2, .., 10\}$. Main characteristics of the dataset are described in Table 1.

Algorithms

Motivated by related work [8], we used algorithms from the MyMediaLite Recommender System Library [2], concretely, the implementations of k-NN, Matrix factorization, Biased matrix factorization, Global Average, User-Item bias and SVD++ techniques.

Hyperparameters and Cross-Validation

We have used 3-fold cross-validation for testing the proposed framework as follows: In each of the 3 iterations, one fold was used for testing. From the remaining two folds, one was used for tuning the hyperparameters of the model validated on the remaining fold. Hyperparameters (the number of neighbors, factors and iterations, learn rate and regularization term) were tuned using grid search. The best hyperparameter combinations for each method are reported in the Table 2. The final model was trained with the best found hyperparameter combination using all the remaining two folds. Finally, the root mean squared error

$$RMSE = \sqrt{\frac{\sum_{ij \in \mathcal{D}^{test}} (p_{i,j} - \hat{p}_{i,j})^2}{|\mathcal{D}^{test}|}} \tag{13}$$

was measured on the test fold.

[3] Collected from the "Programming Algorithms Complexity" course at the Institute of Computer Science at Pavol Jozef Šafárik University during the years 2010–2012

Table 2 The best hyperparameters found by grid search

Method	factors	iter	learn rate	reg. term	k
k-NN	–	–	–	0.15, 0.015	4
MF	6	30	0.405	0.25	–
BiasedMF	14	25	0.455	0.15	–
Global Average User-Item	–	–	–	–	–
SVD++	–	–	–	0.05, 0.015	–
	12	35	0.355	0.15	–

Table 3 RMSE averaging on the validation folds for all models

Model	k-NN	MF	BMF	GA	UIB	SVD++
RMSE	3.0225	3.5114	2.9045	4.1918	2.9958	2.9287

Results

Table 3 presents averaged results of the RMSE for the tested techniques denoted as *k-NN*, *MF* (Matrix Factorization), *BMF* (Biased MF), *GA* (Global Average), *UIB* (User-Item bias), *SVD++*.

The histogram of differences between errors and overall test triple data for all models is shown on the Fig. 1. In cases MF, BMF, UIB, kNN and SVD++, the errors of prediction are very similar and are much better (models predict in many cases correct results) like in the case of the Global Average model which we also expected.

Conclusion

This paper investigates the question if the CF (MF) techniques are usable for student performance prediction or task recommendation in case of small and dense data set. Our experiments on a small and dense dataset show that these techniques are usable but compared with the results of Thai-Nghe et al. provided on a large and sparse KDD Cup 2010 dataset [7] are much less precise. We can conclude, that in case of such a small and not so sparse dataset we have to utilize other information about the students and/or tasks available. The research questions remaining to investigate are the following: Which are the tresholds for the sparsity and size of the dataset above which there is worth to predict student performance with

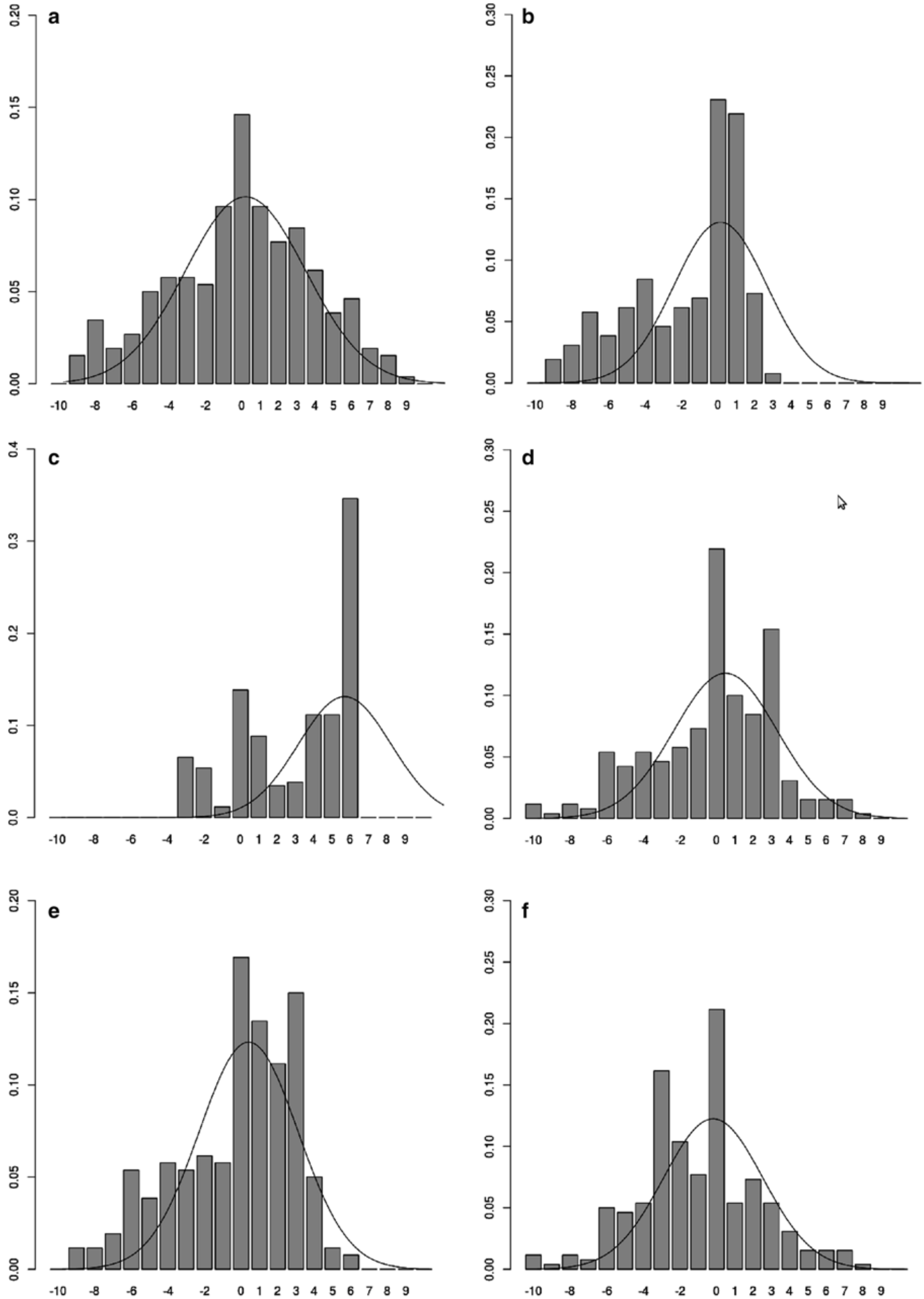

Fig. 1 The histogram of the ratios of errors of all triple data in the validation fold w.r.t the differences in predicted and test value, (**a**) MF, (**b**) BMF, (**c**) GA, (**d**) UIB, (**e**) SVD++, (**f**) kNN

collaborative-filtering techniques? What information to collect about the student and tasks to get better predictions?

Acknowledgements This work was supported by the grants VEGA 1/0832/12 and VVGS-PF-2012-22 at the Pavol Jozef Šafárik University in Košice, Slovakia.

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Career Center System Software Architecture

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Abstract

In today's world, thousands of job seekers are looking for a new job. On the other hand, thousands of employers are trying to find new employees. So, this is a chaotic matching problem and it does not have a certain answer. Companies are searching career centers and web-based career software to find an answer for the question of ""Should we find a convenient worker for a certain role and hire this person or not?" Solution is that simple; just have a look at the beginning of the story: university career centers. In this study, a Career Center System Software has been designed and implemented for matching students with their ideal job. Career Center System Software (CCSS) is programmed on C#, MS-SQL and .NET platform. CCSS has been developed on Visual Studio 2010. CCSS is implemented in a way so as to enable the user to apply for the job announcements and to monitor courses and to call for conferences and seminars. Furthermore, CCSS enables companies to view the applicant's curriculum vitae. All job announcements, educations, seminars and CVs are stored on the database. Software quality and testing shows that CCSS is implemented successfully and ready to use tool as Career Center Software.

Keywords

Software architecture • Database application development • Web-based application development

Introduction

There is a growing need in students to search and find a good, ideal part-time or full time job for themselves. The same problem occurs also in companies; they cannot find appropriate, reliable students, trainees and employees to work in their company. Today, most career web sites cannot respond to their needs completely. Most companies cannot trust applicants and many students do not know the companies entirely. In this context, a career website specific to university greatly satisfies the need. Such a website is very reliable for both students and companies. Therefore in this paper the aim is to design a Career Center System Software (CCSS) as a website which not only satisfies the needs but also gives students the opportunity to view current educations, courses, seminars and conferences in the university.

Determination of the User Requirements

Career Center Software should meet the requirements of the users. Briefly all user requirements such as storing CVs, announcements, publishing courses and conferences should be met and graphics user interface should have an excellent

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_17,

and attractive design. Following sub-chapters explains the user requirements.

Storing CVs

Career Center webpage should include CV Storing module. User (student) needs to enter information about his/her CV and he/she needs to apply to announcements in the website with this CV and brief text.

Storing Announcements

Career Center webpage should be able to store announcements given by companies. Their activity time, their requirement should be stored for students to see them and apply them.

Storing and Publishing Courses and Seminars

Career Center webpage should enable companies to store and publish announcements of the courses and seminars. On the other hand it should enable students to view them.

Graphic User Interface: GUI

Career Center webpage should enable users to understand the software by means of well-organized graphic user interface. This interface can also provide users to spend more time in websites.

After gathering all user requirements and information, we determine software design state which is quite important for the project. The career center software architecture should be well organized, and Career Center System Software should perfectly and clearly be coded, tested and debugged. In the following section, software design stages are explained.

Career Center System Software Design Stages

Design procedure contains the following stages: project planning, database design, web programming, web design and documentation.

Project Planning

After we determined the user requirements, we planned the stages of project, sharing of duties and time management as a group and with supervisor.

Database Design

At the first stage, we obtained E-R diagram, physical and logical database in which we store announcements, CVs, companies and students.

Web Programming

After the design of database, we coded the CCSS software in C#, .NET and Visual Studio. At this stage workflow of the software is designed and constructed.

Web Design

Web design is important for users. CCSS should attract the most of the job seekers and employers. Graphic User Interface is designed for easy to use criteria.

Documentation

A good documentation is important for other users to understand Career Center System Software. It is a manual when users use it as a help resource kit.

Software Tools

A set of tools are used for the implementation of the project. Briefly a database design tool, a web programming tool and a web design tool are necessary for this type of software.

Database Design Tools

In this study, Microsoft SQL Server 2008 is used for the design of the database. Oracle is another alternative, but Microsoft SQL Server is more compatible with our development tools.

Web Programming Tools

C# and .NET are preferred to program the website in this project, because of its user friendly characteristics.

Web Design Tools

Photoshop CS5, Java Script and Visual Studio 2010 tools are used to design CCSS website.

Implementation

In this section, there is a close look to implementation steps, work flow and software architecture. All data and process flows will clearly be explained. Even it does not seem so complex on the interface level, there are many process running behind to provide efficient function of the system.

Database Design Tools

Database design is one of the most important components of Career Center System Software. Microsoft SQL Server and Oracle are two of the leading enterprise database systems. Microsoft SQL (MS SQL) Server is preferred for database design. MS SQL is a relational web hosting database that uses stored website information like blog posts or user information. MS SQL is the most popular type of database on Windows servers. It is not free but it has many advanced features that make it suitable for business applications. Basically, an MS SQL database is capable of storing any type of that we want. It will let us quickly store and retrieve information and multiple web site visitors can use it at one time. It is easy to integrate MS SQL Server data in CCSS application, write queries, develop reports, and employ powerful business intelligence systems. We also use the features of buffer management, logging and transaction, concurrency and locking, replication services, analysis services, notification services, integration services, full text search service, stored procedures, triggers and views [1].

MS SQL is the most compatible database running with ASP.Net. This is the very important feature of MS SQL and it is the database of choice for web applications on a Windows platform using .NET or ASP [2]. These languages help connecting a MS SQL database easily. Therefore it is used in our CCSS project.

Application Development: Web Programming Tools

There are a lot of development tools on the market. When building desktop database systems code developers usually use Microsoft Access forms, reports, queries, VBA code or Filemaker forms, reports, scripts or something like .NET code (Visual Basic or C#). Using the built-in tools in Microsoft Access or Filemaker leads to quicker development than using .NET code. However .NET gives more flexibility and control. Client server and web-based development is usually done in Microsoft tools (such as ASP.NET or VB or C#), or Oracle tools, or PHP with My SQL. In this study, C#.NET platform is preferred for creating dynamic web pages on the Windows platform. C# provides easy coding for high-quality, easily deployed Microsoft solutions [3]. C# is intended to be a simple, modern, general-purpose, object-oriented programming language and also have a multi-paradigm programming language characteristics encompassing strong typing, functional, generic, object-oriented, and component-oriented programming disciplines.

Some implementations just like in [4] present a practical approach to building fast and scalable web sites using ASP. NET and SQL Server. In addition to a wealth of tips, tricks and secrets, code developers find advice and code examples for all tiers of applications, including the client, caching, ASP.NET, threads, session state, SQL Server, analysis services, infrastructure and operations.

In the light of these clues, CCSS is developed. To develop CCSS, we install both Microsoft .NET Framework 4.0 and Microsoft Visual Studio 2010 on development machine. Language Integrated Query (LINQ) is also used in this project. LINQ [5, 6] is the part of the .NET Framework that provides a generic approach to querying data from different data sources.

Web Design Tools

Programming languages contain good and bad parts. JavaScript is more reliable, readable, and maintainable than the language as a whole-a subset you can use to create truly extensible and efficient code [7]. With JavaScript, we finally discover an elegant, lightweight and highly expressive language. With JavaScript, we can create effective codes by managing object libraries and we can develop CCSS and its applications for the Web. We also use CS5 together with JavaScript in the design of Graphic User Interface as shown in Fig.1. CS5 which contains Photoshop is used for graphic design. It is flexible and convenient tool for CCSS Software design.

Modules

CCSS is designed as a web application. It includes job-course-seminar announcements, and CVs. All these are stored on the database. Web application has several modules, separated by their specific roles and functions. In this part, the function of each module will be explained step by step. There are six modules in the system.

1. CV Preparation Module
2. Job Announcements
3. Course Announcements
4. Seminar Announcements
5. Advertising Module

Now, here is the explanation for each module of CCSS:

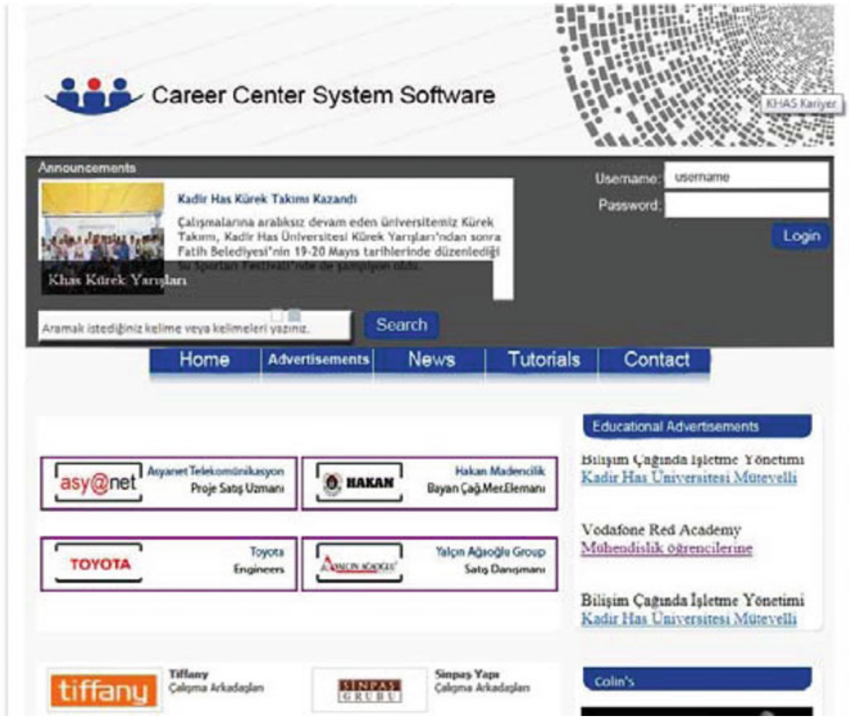

Fig. 1 Graphic user interface of career center system software

CV Preparation Module

This module is unique and the most important part of CCSS. It may help students and job seekers to prepare a CV for job applications. Personal Information Interface of Automatic CV Preparation Module is shown in Fig. 2. This is the first step of applying for a job.

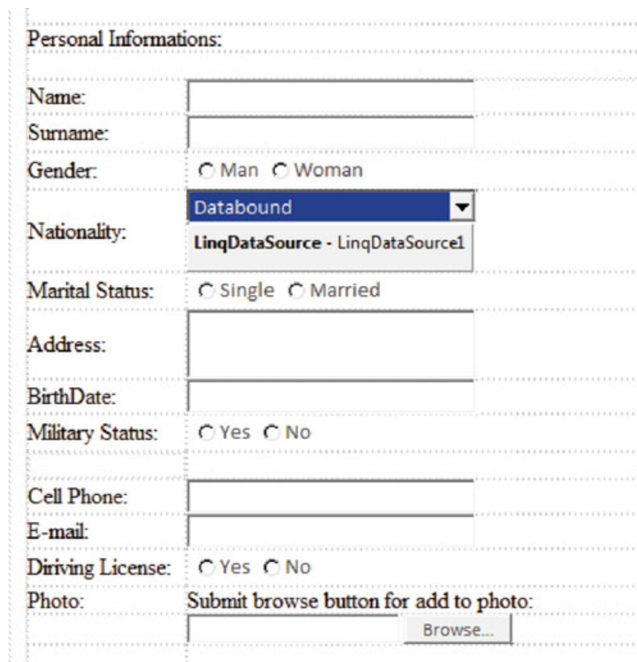

Fig. 2 Personal information interface for automatic CV preparation module

Job Announcements

In this module, companies give the job description and specifications of the employees that they are looking for.

Course Announcements

In this module, departmental course announcements are described.

Seminar Announcements

In this module, departmental or external seminar announcements are described.

Advertising Module

Advertisements are very important in such a web service, so it is a common part of web-based software. Therefore CCSS contains an advertising module.

Users

There are four different types of users in Career Center System Software Architecture. These are;

1. System Administrator
2. Student (User)
3. Company
4. Social Clubs

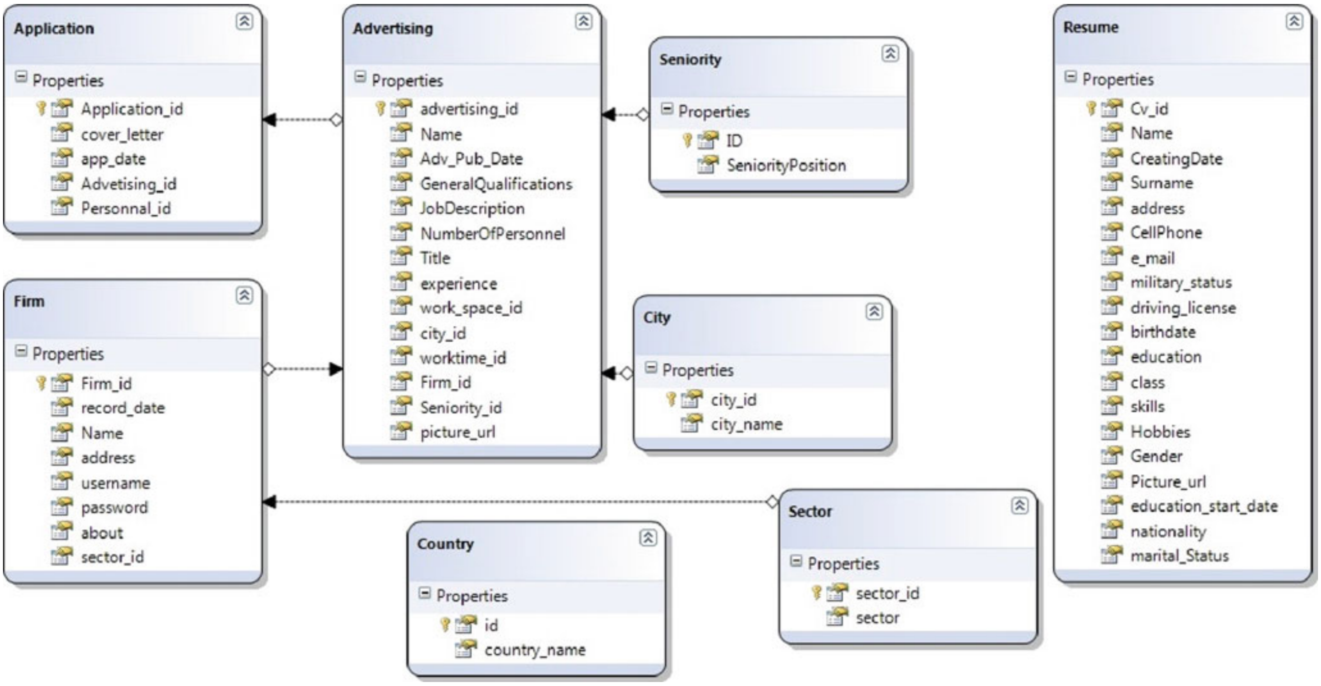

Fig. 3 Software architecture of career center system software

System Administrator

System administrator is authorized to create, edit and delete users, announcements and companies. System Administrator can see all user information and can control all new announcements.

Student (User)

Student or User can see job announcements, course announcements and seminar announcements and also all advertisements. User can use CV preparation module as a first step of job application.

Company

Company or Firm can see all user information. Company can create job advertisements and can edit and delete them.

Social Clubs

Social Clubs can create announcements and can edit and delete them. Social Clubs are only able to see their own announcements.

All these modules are implemented by a professional software architecture design point of view. Use-case diagram and software architecture of Career Center System Software is given in Fig. 3.

Conclusions

In this study, a new, functionally content rich software architecture model of a Career Center System Software is developed, and implemented. We believe that this level of implementation detail does not commonly appear in the literature. So this is a significant contribution of the paper.

After project planning, and time management, Career Center System Software project is successfully completed. The software satisfies most of Career Center goals. Career Center System Software helps students, employees, and also companies. This software is implemented as a webpage application. Updating CCSS to more intelligent software will be a future work of this project.

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Mobile Camera Source Identification with SVD

A.-R. Soobhany, K.P. Lam, P. Fletcher, and D.J. Collins

Abstract

A novel method for extracting the characterising sensor pattern noise (SPN) from digital images is presented. Based on the spectral decomposition technique of Singular Value Decomposition, the method estimates the SPN of each image in terms of its energy level by first transforming the image/signals into a linear additive noise model that separates the photo response non-uniformity (PRNU) of the associated camera from the signal subspace. The camera reference signatures of the individual cameras are computed from a sample of their respective images and compared with a mixture of image signatures from a set of known camera devices. The statistical properties of the method were studied using the Student's *t*-test constructed under the null hypothesis formalism. Our studies show that it is possible to determine the source device of digital images from camera phones using such method of signature extraction, with encouraging results.

Keywords

Source identification • Singular value decomposition • Digital image forensics • Sensor pattern noise • PRNU • Mobile camera phone

Introduction

Digital images that are created by digital cameras found in bespoke cameras, mobile phones, tablets or video camcorders can be used for illicit purposes and for the commission of crime. When a forensic investigator recovers images from a suspect source, for example a mobile phone or any secondary storage, s/he may want to identify the source device that created the image to be able to link the images to a suspect or find out if the content of the images has been tampered with. When an image is created in the camera pipeline, described in [1], traces or artefacts of the camera processing are left in the image. The artefacts can be used as digital fingerprints or signatures to identify the source device that created the image. Several techniques exist to use these artefacts for identifying and linking source devices, such as lens aberration, colour filter array (CFA) interpolation and demosaicing, camera response function (CRF), JPEG compression, higher order wavelet statistics and relevantly sensor pattern noise (SPN) or photo response non-uniformity (PRNU). The first and last methods are often used to identify the specific source device that generated the image.

Until recently, the most prominent method to extract the PRNU has been to use a wavelet extraction filter that extracts in the wavelet domain the medium to high frequency subbands in which the PRNU lies [2]. As such, the extracted signature contains a mixture of different types of noises including the desired SPN or PRNU, random noise, fixed

This project was funded by Acorn fund of Keele University, UK. Forensic Pathways Ltd, UK funded background work on this project and provided technical support.

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313, DOI 10.1007/978-3-319-06773-5_18,

pattern noise (FPN) and any high frequency scene details. The SPN consists mainly of the FPN and PRNU noise, and the latter is unique to the individual sensor of a camera. The FPN is caused by dark currents when the sensor is not exposed to light and is usually removed by some cameras. Further work has been done to reduce the FPN and other random noises to obtain a cleaner sensor pattern noise. The signature can be enhanced by reducing the high frequency scene details which pollute the signature [3].

The PRNU is a multiplicative noise whose magnitude is proportional to the intensity of light falling on the sensor, and has a relatively low energy in general. If the PRNU can be converted to an additive noise, it can be, in principle, much easier to extract the signature from the image using linear techniques. Furthermore, given the relatively well established range of energies associated with the PRNU, the latter can be separated from other polluting noises present, thus resulting in a 'cleaner' noise signature. This paper presents a novel method for extracting the PRNU of digital images produced by mobile phone cameras. Using the spectral decomposition technique of Singular Value Decomposition (SVD) to separate the image into a sequence of rank-one images with descending order of energies, the extraction of the PRNU is eased by used of homomorphic filtering technique that represents the original image in the logarithmic domain where the inherently multiplicative PRNU is converted to an additive noise [4]. Initially, the number (and choice) of ranks used to represent the SPN is determined empirically by means of the percentage of energy present in the PRNU relative to the entire image. Experiments were performed on five models of mobile phones. Two handsets of each model, 10 cameras, were used to demonstrate that the signature obtained by our method is both unique and consistent; thus enabling the differentiation between individual devices of the same camera model. The approach is similar to that used by Gul and Avcibas, who studied the relative linear dependency of image rows/columns by means of the SVD with the CFA interpolation algorithm developed to identify the model of a mobile phone [5].

The rest of the paper is organised as follows. The background on digital image forensics and device identification is reviewed in section "Digital Imager Forensics and Device Identification", which is followed by a summary description of the current PRNU extraction methods in section "Signature Extraction of SPN/PRNU". The SVD technique is described in section "Singular Value Decomposition", which leads to an elaboration of our signature extraction model in section "Signature Extraction Model". The experimental procedures are described and the results are explained in section "Experiments and Results" followed by a discussion of the results in section "Discussion" and finally the conclusions in section "Conclusion".

Digital Imager Forensics and Device Identification

Digital image forensics can help an investigator obtain the information and knowledge about a source device that created some suspect images. The artefacts left behind in the digital image by the camera can be from the characteristics of the imaging device itself or the processing inside the device [6]. In general, forensic investigators do not have any previous knowledge about the source of the images they recover and digital image forensics usually works as a 'blind' approach without needing à priori knowledge about the images.

The identification of the CFA interpolation and demosaicing algorithms present in digital images can be performed by calculating the correlation between the different colour channels in a colour image and estimating the demosaicing algorithm used to produce the image [7]. Lens radial distortion occurs when straight lines from the object are rendered as curved lines on the sensor of the camera and the difference between the distorted line and the straight line can be measured and used to identify the camera [8]. Quantization tables vary between camera manufacturers and different camera models from the same manufacturer [9]. Digital images are usually recompressed for storage or transmission and in these cases the original source device can be identified [10]. The CRF can be estimated by finding the mapping algorithm using a single image, and the imaging device can be identified as the source of that image [11]. Also, higher-order wavelet statistics have been applied for camera model and make identification, together with binary similarity measures and image quality measures as well as a SVM classifier [12].

The CFA, CRF, JPEG compression and statistical techniques can be used to identify a particular model or make of a camera whereas the lens aberration and SPN can be used to ascertain distinct devices of the same model. Camera lenses can be changed readily whereas the camera sensor is much harder to change as well as being more expensive and hence it is uncommon for a sensor to be changed. This makes the SPN a better camera signature than lens aberration.

Signature Extraction of SPN/PRNU

The SPN consists mainly of the PRNU noise that is unique to the individual sensor of a camera [2]. It can be used to identify source devices as well as to determine whether an image has been tampered with [13]. The PRNU is due to imperfections arising from the manufacturing process of the sensor and due to slight variations in conversion of light to electrical energy by individual pixel sensors [14]. A combination of the uniqueness of the imperfections in the silicon material and the different sensitivity of the pixels makes the PRNU ideal for differentiating between sensors, even if they are made from the same silicon wafer, and hence the respective cameras into which they are embedded.

Two most commonly used denoising filters for signature extraction are the Gaussian filter in the spatial domain and the wavelet domain based approach. The Gaussian filter is two dimensional where the variance of the filter can be varied to choose the cut-off frequency that will determine the level of scene content and sensor noise [15]. The second approach applies wavelet decomposition to represent the image in decomposition to represent the image is applied to the details from which an image reconstruction is performed to obtain the noise free image. The denoising filter is described in details in [2]. The PRNU, n, which appears as a high frequency signal, can be extracted from an image, I, based on the model proposed in [2] as a high pass filter:

$$n = I - f(I) \tag{1}$$

where f is a denoising function, which acts as a low pass filter to aid the extraction of the desired spectrum of noise from the image.

The multiplicative nature of the PRNU has made it particularly susceptible to scene details. For mobile phones, in addition, it can also be contaminated by the blockiness (row/column noise) created by the JPEG compression and other processing operations performed in the camera pipeline. Consequently, further processing is often applied to facilitate the estimation of the SPN, including the attenuation of non-unique artefacts (NUA) such as the FPN, blockiness and colour interpolation [13]. The accuracy of SPN can also be improved by attenuating the interference of scene details with the enhancer described in [3], where the enhanced SPN was shown to increase the identification rate and allows the use of smaller image crop size. However, these methods did tend to decrease the overall quality and strength of the SPN, which is already a weak signal.

In general, the identification of source devices is performed by extracting the digital signatures from a number of images, say, 50 pictures from each camera. The average of these signatures is calculated to form the camera reference signature. The signatures of recovered suspect images are extracted and compared against the camera reference signature for possible matches. Two comparison methods are commonly used; namely, Peak to Correlation Energy (PCE) measure and cross-correlation coefficient (CCC). Broadly speaking, the PCE is a more stable test than correlation method, particularly when the image has undergone geometrical manipulations [14].

Singular Value Decomposition

Signal decomposition is an important practical problem as the energy in most real-world signals has unevenly distributed frequency spectra [16]. Using signal compaction techniques, the energy of a signal can often be redistributed into a significantly smaller number of frequency sub-bands, allowing them to be divided into sub-spectra in order that those with more energy content will be given a significantly higher priority for further processing. By analysing and discarding signal subspaces with lower priority, a signal can be reconstructed or approximated by a decomposition-synthesis procedure that is widely adopted in such practical applications as signal compression/coding. Additionally, such a procedure also forms the mathematical basis of modern time-frequency based techniques for analysing signal subspace, providing relevantly an expansive means of spectral analysis that naturally leads to the transform coding methods representative of the eigen-decomposition approach of spectral estimations.

Most eigenvector approaches work by separating a multidimensional signal into two subspaces, which are commonly referred to the signal and noise subspaces. By convention, the ensuing transform generates eigenvalues in decreasing order and eigenvectors that are orthonormal, allowing eigenvectors that are part of the noise to be identified and eliminated. In practice, the most challenging part of eigenvector spectral analysis is to compute the appropriate dimension of the signal or noise subspace, which often resorts to a trial and error procedure. Mathematically, a matrix A with m rows and n columns with rank r, $r \leq n \leq m$, can be expanded or decomposed into:

$$A = USV^T \tag{2}$$

where U and V^T are two orthogonal matrices of size mxm and nxn respectively [17]. S is the diagonal matrix, of size mxn, containing r non-zero singular values. The decomposition of matrix A is known as Singular Value Decomposition (SVD). When an image is decomposed using SVD, the ranks of the image can be represented as component matrices with decreasing energy contents as shown in Fig. 1 [18]. SVD can be used to separate the spectra of the image and the ranks can be selected in accord with the aggregated total image energy of individual ranks; that is, sum of λ_i^2, where λ_i represents the eigenvalue associated with that eigenvector (e_i).

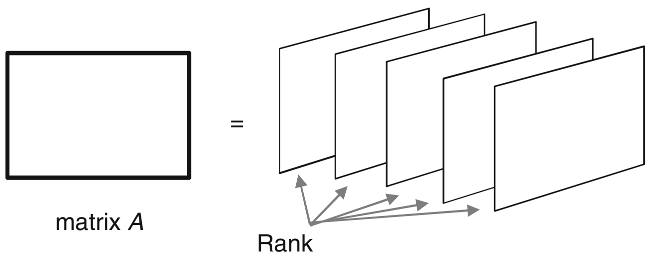


Fig. 1 SVD of matrix *A* with each rank as a separate matrix

Signature Extraction Model

The wavelet based signature extraction method described in section "Signature Extraction of SPN/PRNU" is most widely used, as it provides better identification results than the Gaussian filtering approach [3]. The method selects a wavelet filter/family to extract the PRNU by high-pass filtering in the frequency domain, resulting in scene details being included in the extracted signature. In particular, PRNU is a multiplicative noise and consists of additive low frequency defects (e.g. dust particles on lens) and the pixel non-uniformity (PNU) [2]. In practice, the noise used for identifying the individual source camera is the PNU, since the low frequency defects are removed by averaging several images or high-pass filtering as part of the denoising process. PRNU is not a temporal noise which means it is a spatial noise only with a multiplicative spatial variance. A simplified model for a noisy image I can be represented as

$$I = I_0 + I_0.K + \eta \tag{3}$$

where I_0 is the clean image (perfect absorption of light energy by pixels), K is the PRNU and η is the remaining noise, such as shot noise, dark noise and read-out noise, associated with the image. The noisy image is comprised of the clean image to which is added the product of the clean image and PRNU. The model can be represented as

$$I = I_0(1 + K) + \eta \tag{4}$$

If the image model is converted from the spatial domain to the logarithmic domain, the multiplicative noise model is transformed to an additive noise model in the logarithmic domain [19]. Thus, the result is an additive model consisting of the image and PRNU noise, as follows:

$$\acute{I} = \acute{I}_0 + \kappa \tag{5}$$

where $\acute{I} = \log(I)$, $\acute{I}_0 = log(I_0)$, $\kappa = log(1 + K)$ and the noise η is cancelled by averaging many images created by the sensor.

The energy of the PRNU in an image depends on the type of device that produced the image and is a fraction of the total energy of the image. There are two types of sensors that are primarily used in digital cameras, the CCD (Charge-Coupled Device) and the CMOS (Complementary metal–oxide–semiconductor). The CCD produces less noise but requires more power when compared to the CMOS, hence the reason CMOS is used most often in camera phones where space and battery life are crucial. The energy of the PRNU in a CMOS will be affected by other sources of noises and the average power (variance) of the PRNU can be reduced [20]. The PRNU in CCD was measured by calculating the variance (σ^2) of the noise in 100 image sets [21]. The energy of the PRNU can be estimated to be in the range of 0.01 %–1.5 %, depending on the type of image and sensor.

The logarithmic image model is then decomposed into ranks using SVD. The ranks are in descending order of relative energy of the image. The partial logarithmic image is reconstructed using a selected range of ranks in accordance with their associated energy. The latter should be chosen to contain the PRNU of the camera that created the image. If the digital signature is converted from the logarithmic domain back to the spatial domain the original image cannot be recovered, which signifies that the signature can be stored or transferred securely. The signatures extracted by this method can be used to create the camera reference signatures of the source device for identification purposes or compared against the reference signatures of other cameras for linkage purposes.

Experiments and Results

For the purpose of our experiments, a total of 1,000 images were chosen evenly from 10 mobile phones; i.e., each device contributed 100 images. Most of these phones were older models of the respective make and, as such, offer a significantly lower image quality, particularly when compared with images taken from digital cameras. To demonstrate that our method can differentiate between devices of the same make and model as previously explained in section "Digital Imager Forensics and Device Identification", there were five different makes/models, each of which has two phones.

Table 1 shows that, for each model, the two phones share the same prefix but are distinguished by different labels 'A' and 'B'. Most of the phones are products from Nokia, since it is one of the most popular makes in the low-to-medium end of the camera phone market. In addition, the inclusion of different phone models from the same make was also expected to better demonstrate the identification performance of our method. In all cases, the pictures were taken at the highest native resolution of the cameras and stored in the JPEG format, which is the de facto compression format for still images from camera phones. To ensure generality, the pictures were natural images consisting of a mixture of outdoor and indoor scenes, captured during the day and at night. Further, given the expectedly different sizes of the captured images, due to the different quality of the camera phones, they were all cropped to the same size of 512 × 512 pixels, consisting of the top left corner of the image as described in [1].

The SVD-based signature extraction procedure was applied to these cropped images, allowing the creation of reference signatures for the individual cameras. This was achieved by selecting 50 images randomly out of the 100 sample and then averaging the extracted signatures as per the commonly adopted procedure (described in section "Signature Extraction of SPN/PRNU"). The remaining 50 signatures from each camera dataset were then compared against the 10 camera reference signature computed for the 10 cameras. Cross correlation was used to match the signatures of the test images against the 10 camera reference signatures since there was no geometrical transformation applied to the images and our test was mainly to check the effectiveness of our proposed extraction method. It has been shown in previous research in source device identification that an acceptance threshold of 0.01 for the cross correlation coefficient was reasonable [3].

Table 1 Mobile phone names and aliases with maximum image resolution

Mobile phone	Alias	Max image resolution
nokia_C2_01_A	cam_1	1,536 × 2,048
nokia_C2_01_B	cam_2	1,536 × 2,048
nokia_E72_A	cam_3	2,592 × 1,944
nokia_E72_B	cam_4	2,592 × 1,944
nokia_N95_A	cam_5	2,592 × 1,944
nokia_N95_B	cam_6	2,592 × 1,944
samsung_galaxy_S2_A	cam_7	3,264 × 2,448
samsung_galaxy_S2_B	cam_8	3,264 × 2,448
zte_orange_sanfrancisco_A	cam_9	1,536 × 2,048
zte_orange_sanfrancisco_B	cam_10	1,536 × 2,048

The required energy range for the extraction of the PRNU was found to vary greatly depending on the amount of scene detail in the image. Images with high scene detail content will have their energy spread out more widely across the top ranks after performing SVD, whereas less 'busy' images had most of their energy concentrated among the first couple of high energy ranks. Figure 2 shows the plot of the *log*-scaled singular values of a natural image with 512 ranks. There is a sharp drop after the first rank (from 7.6 to 4.4). For a blue sky image, the drop is from about 7.8 to 0.4. The first rank holds most of the scene detail energy.

The graph in Fig. 3 shows the result of comparing the camera signature of the ZTE Orange San-Francisco A (*cam_9*) with the test signatures of 10 images from each camera. The graph in Fig. 4 shows the result of comparing the camera signature of the ZTE Orange San-Francisco B (*cam_10*) with the same test signatures as before. Figures 5 and 6 show the result of using blue sky images and normal scene images to create the camera reference signature of *cam_5*. Tables 2 and 3 shows the mean and standard deviation of correlation coefficient values, respectively, when the 10 camera reference signatures, extracted using SVD method and wavelet method, are compared with the test images from the same camera and rest of the cameras. The same images were used to extract the sets of signatures using the wavelet and the SVD extraction method.

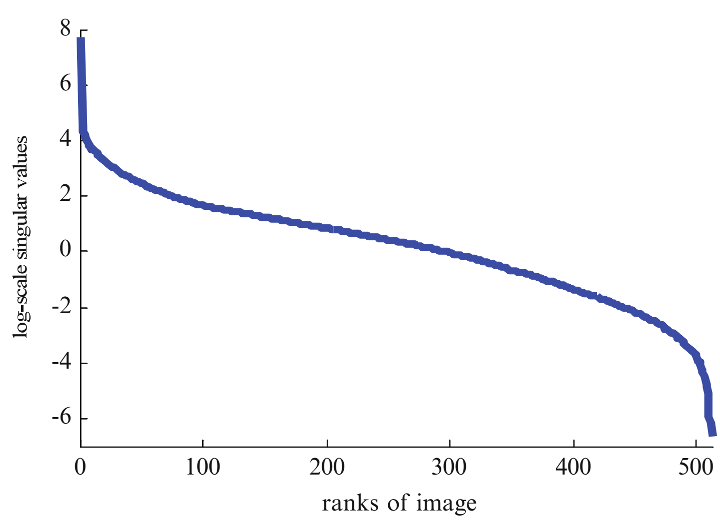


Fig. 2 Plot of *log*-scaled singular values of a natural image with 512 ranks after SVD decomposition

Fig. 3 zte_orange_sanfrancisco_A: Images 81–90 come from this camera, 91–100 from *cam_10*. *Red* dotted line is the acceptance threshold

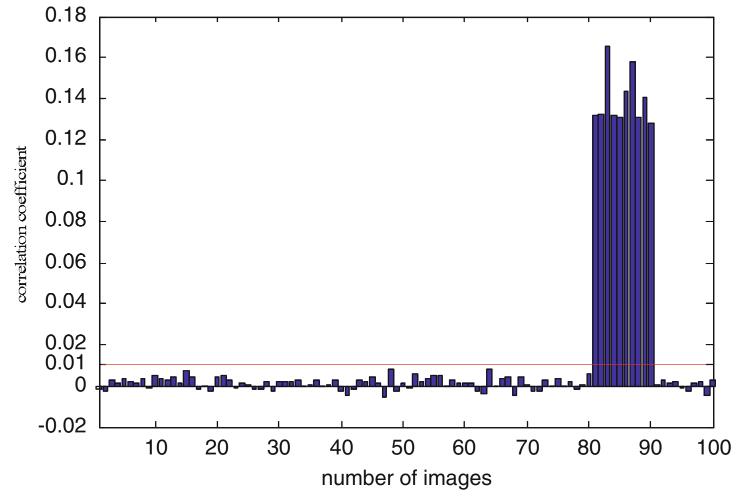
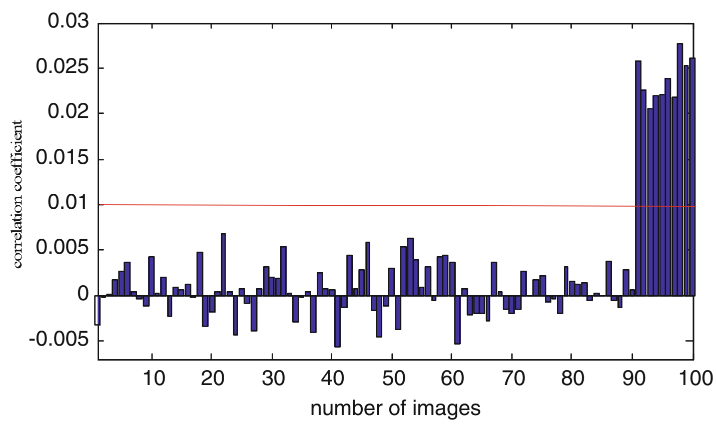


Fig. 4 zte_orange_sanfrancisco_B: Images 91–100 come from this camera, 81–90 from cameras 9. *Red* dotted line is the acceptance threshold



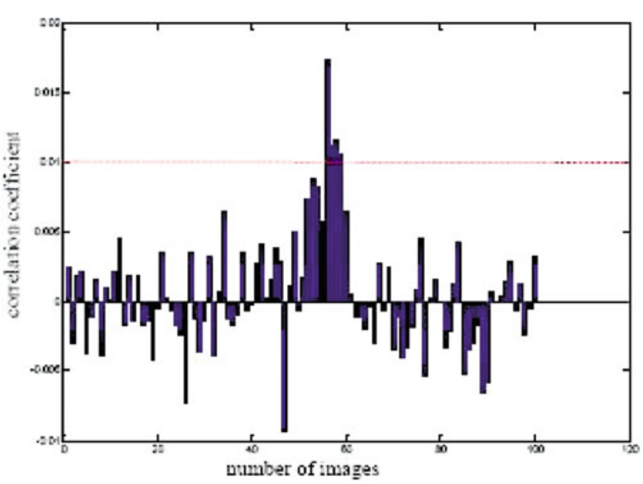


Fig. 5 zte_orange_sanfrancisco_B: Images 91–100 come from this camera, 81–90 from cameras 9 *Red* dotted line is the acceptance threshold

Discussion

The empirically selected range of rank-one images to (best) approximate the signature was found to be between 50 and 150 inclusive, with the test images cropped at a size of 512×512 pixels [22]. It can be seen in Fig. 3 that the correlation coefficient for the images from *cam_9* is significantly higher than the acceptance threshold, whereas the correlation coefficient for the other cameras is close to zero confirming the expectedly uncorrelated relationship. Furthermore, the identification results between images from *cam_10* and the reference signature of *cam_9* is similar to the results of other cameras, clearly demonstrating that our method can differentiate between two cameras of the same model. Figure 4 corroborates the results from *cam_9* when using the camera reference signature of *cam_10*, although the correlation values for test signatures from

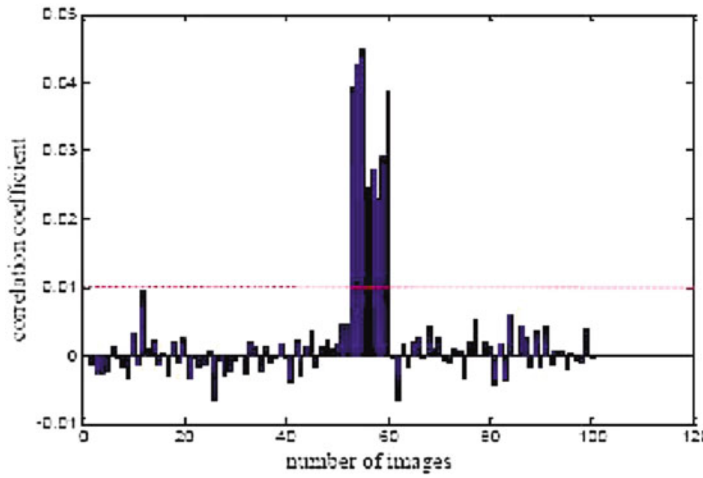


Fig. 6 Nokia_N95_A camera: Images 51–60 come from this camera and the rest from the other 9 cameras. *Red* dotted line = acceptance threshold

Table 2 Mean of correlation coefficient values obtained using SVD method and wavelet method

	Images from same camera		Images from other cameras	
Camera numbers	*SVD*	*Wavelet*	*SVD*	*Wavelet*
cam_1	0.0238	0.0077	0.0006	–0.0002
cam_2	0.0327	0.0107	0.0077	0.0003
cam_3	0.0268	0.0115	0.0070	0.0001
cam_4	0.1253	0.0715	0.0020	0.0002
cam_5	0.0187	0.0038	0.0088	0.0001
cam_6	0.0355	0.0037	0.0096	–0.0001
cam_7	0.0139	0.0064	0.0010	0.0001
cam_8	0.0748	0.0205	0.0065	0.0000
cam_9	0.1394	0.0511	0.0013	0.0000
cam_10	0.0238	0.0077	0.0006	–0.0002

Table 3 Standard deviation of correlation coefficient values: SVD method vs. Wavelet method

	Images from same camera		Images from other cameras	
Camera numbers	*SVD*	*Wavelet*	*SVD*	*Wavelet*
cam_1	0.0598	0.0039	0.0203	0.0017
cam_2	0.0107	0.0045	0.0104	0.0014
cam_3	0.0079	0.0077	0.0093	0.0013
cam_4	0.0233	0.0198	0.0044	0.0015
cam_5	0.0116	0.0014	0.0121	0.0014
cam_6	0.0088	0.0011	0.0149	0.0012
cam_7	0.0032	0.0028	0.0029	0.0016
cam_8	0.0087	0.0154	0.0094	0.0015
cam_9	0.0127	0.0135	0.0028	0.0014
cam_10	0.0023	0.0039	0.0023	0.0013

cam_10 are lower as shown in the figure. Preliminary studies suggest that this was largely due to the quality of the images that we selected (at random) to create the reference signature of *cam_10*; in particular, there were more saturated pixels present in these pictures.

The method appears to work better with natural images when generating the camera reference signature. Figure 5 illustrates that the majority of false negatives were attributed to *cam_5*, suggesting that the extracted PRNU from those 'blue sky' images was relatively weak. On the other hand, Fig. 6 shows no false negatives whilst a near false positive has been identified (image 12) having a computed correlation value very close to the threshold of 0.01. The mean values (Table 2) of the correlation coefficient values are higher for the SVD-based method when the camera reference signatures are compared with signatures from the same cameras. For some of the cameras (1, 5, 6, 7 and 10), the mean correlation values for wavelet method is lower than the acceptance threshold, indicating that a significantly large number of results were false negatives. For the SVD-based extraction method, the signatures obtained respectively for cameras 1, 3 and 5 generated noticeably fewer false negatives, than that produced using the wavelet approach. For cameras 7–10, the SVD-based approach provided much better results than the wavelet approach.

The statistical properties of the samples collated were examined using the Student's *t*-test (William Gossett 1876–1937) formalism to determine if our experimental results are significant or accidental. To facilitate the investigation, individual spectra representing independent measurements of a sample/signature are investigated by means of the spectral similarity measure of SAM (Spectral Angle Mapper) [23]. Here, our tests were formulated in the mathematical framework of multi-spectral signatures that determined the similarity of sample spectra by attributing a reference signature to the spectral responses or measurements of the individual sample set [24]. The advantages are fourfold; (1) SAM is insensitive to illumination measured at the individual spectral bands, particularly in cases of high data dimensionality where M is large (~1,600 in our case), since the algorithm uses only the multidimensional vector direction and not its length. (2) Whilst pattern classification and hypothesis testing address problems that are somewhat different, they are closely related under the formalism of SAM. (3) Broadly speaking, SAM shares the same data reduction principle of projection pursuit (PP) of which the widely used PCA method is a special case, whilst other, more sophisticated component analytic procedures yield curved surfaces embedded in the full multidimensional space on to which arbitrary (spectral) patterns can be projected [25]. (4) The theoretical framework of SAM can readily be extended to incorporate advanced data analytics, including Spectral Information Divergence (SID) that has been shown to be more robust when the sample sizes are limited [24].

Conclusion

A novel PRNU extraction method using SVD was introduced and demonstrated to be able to distinguish between camera phones of the same model. The extraction model described how SVD can be used as an image decomposition method for which signatures can be exacted from the individual images that can be associated with the respective source devices. The identification results of the test performed on 10 cameras showed that our method can differentiate between two cameras of the same make and model, suggesting that the signature is highly related to the SPN of the camera.

We also showed that the PRNU signature could be extracted relatively straightforwardly with most real-world/natural images other than the representative uniformly lit (e.g. blue sky) pictures, which are difficult, if not impractical, to obtain from recovered evidence in most forensic investigations. The performance of the SVD-based method was also compared to the wavelet method and the former did produce encouraging results. Further work, particularly on testing of automated algorithms for rank selection given the image characteristics, and classification performance including images of differing resolution and size, is underway.

Acknowledgment We are indebted to the generous support of Willy's World, UK for providing some equipment. Special thanks also to Sofia Shah for providing her personal phones as well as participating in the image acquisition process.

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Comparison of Manual and Image Processing Methods of End-Milling Burr Measurement

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Abstract

This paper compares the results for manual method of burr height measurement with the image-processing technique for end-milled work-pieces under various conditions. The manual method refers to the traditional way where a few readings are taken at random locations using a microscope and the burr height is approximated with an average value. In contrast, the image processing technique analyzes the whole burr profile as seen through the lens of the microscope and captured using a digital camera. With the results obtained using the image processing method as reference, the results show a significant difference between the two average readings in most cases and generally the percentage error is greater for work-pieces with irregular burrs.

Keywords

End-milling • Burr height • Image processing

Introduction

Burr formation during machining processes, such as an end-milling operation, are unwanted and often require deburring operations which has been made possible with continuous developments in computer-aided manufacturing (CAM). However, before deburring can be carried out, determining the size of the burr and its location would be required [1].

Various research work also focus on predicting the best milling conditions that would produce minimum burr. One such work is presented in [2] which utilizes the hybrid group method for data handling (GMDH) network to predict burr formation under different conditions in an end-milling operation. An integral phase of such work is carrying out burr height measurement under various milling conditions and then using this data to train the network based on which it makes predictions.

While microscopes of very high resolution have been developed over the years, the often irregular burr profile implies that the few readings normally taken using the manual method of burr height measurement would not give a correct impression of the burr profile or its average value. As such, no matter how sound the prediction technique is, the predicted data may not be totally correct primarily because of the imprecise data with which the network was trained.

This paper takes an advanced approach to end-milling burr height measurement by employing the image processing technique, similar to the work of [1, 3–5] and [6] and as presented in [7], and compares the results against the manual measurement method, which is presented in [2]. While there are many similar off-the-shelf products which can be used for this purpose, the image processing method employed in this work is simple, economical, and task specific.

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_19,

Experimental Overview

During experimentation, exactly the same work-pieces were used for both the methods with end-milling operations performed on the work-pieces under varying conditions. The steps taken in burr height measurement using the image processing technique are image acquisition and image processing, which involves image pre-processing and burr profile measurement, as outlined in [7]. The image acquisition hardware includes a high resolution digital camera (3,072 × 2,304 pixels) mounted on the viewing lens of the Mitutoyo Toolmaker's microscope as shown in Fig. 1. The microscope is also equipped with a dial gauge and a high intensity light focused on the section of the burr under analysis.

A sample end-milled work-piece for burr height measurement is shown in Fig. 2 and a sample captured image is shown in Fig. 3.

The captured image is transformed into grayscale format for further analysis. To calibrate the system, burr height measurement is firstly performed using the dial gauge along the cross-hair reference of the microscope and the same is then done manually on the image to get the relationship in micrometers per pixel. Based on this, the resolution of the system was determined to be approximately 2.2 μm. Next the edge of the work-piece is automatically determined and used as a reference for making the measurements. The developed vision system also caters for the disorientation of this reference line during image capture. That is, it determines the inclination of the reference line and aligns it to the horizontal axis before taking measurements.

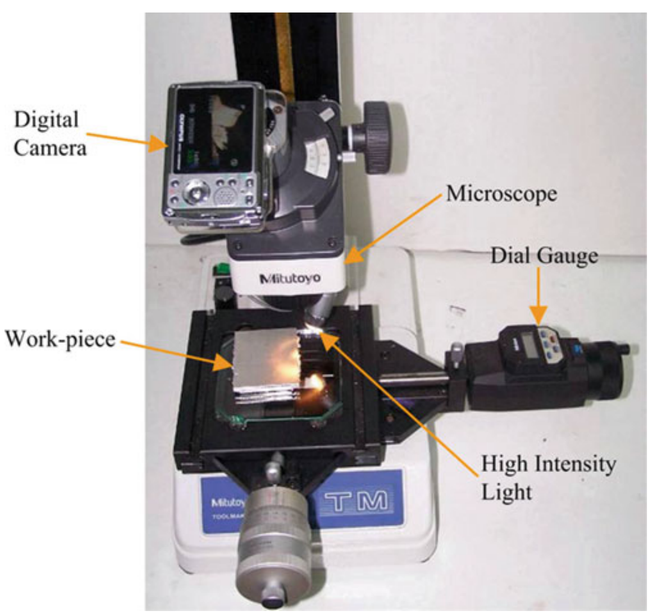

Fig. 1 Image acquisition setup [7]

Fig. 2 Sample work-piece [7]

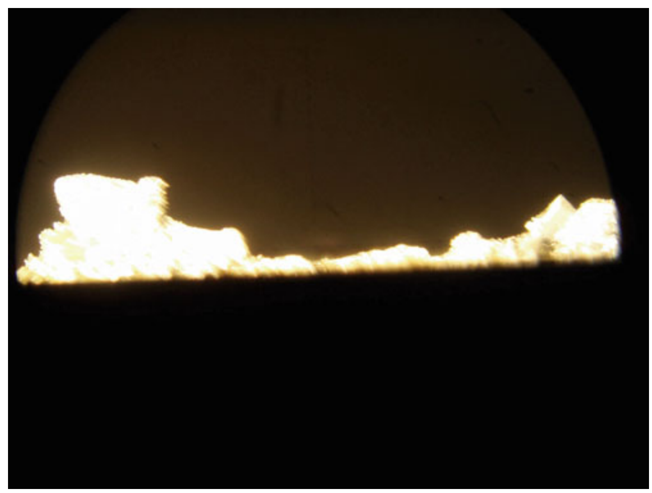

Fig. 3 Sample image [7]

The distance between the horizontal reference line and the burr edge is then measured and multiplied by the calibration value to get the burr height. This is done for the entire length of the burr to obtain the whole burr profile, as shown in Fig. 4 for the sample image of Fig. 3, and the average burr height is then given as

$$\textit{Average burr height} = \frac{\sum_{n=1}^{N} \left(B_{y_n} - R_y\right)}{N} \times C \qquad (1)$$

where B_{yn} is the burr height, in pixels, at the *nth* pixel along the reference line, R_y is the height of the reference line in pixels, N is the number of pixels along the reference line and C is the calibration constant. The horizontal line in Fig. 4 indicates the average burr height.

Three such images were taken and analyzed along a single edge, two on the ends and one in the middle, to carry out the analysis using the image processing method.

The manual measurement setup is similar to that shown in Fig. 1 except that the digital camera is not utilized. Instead, ten readings were taken at random locations using the dial gauge and an average value is determined [2].

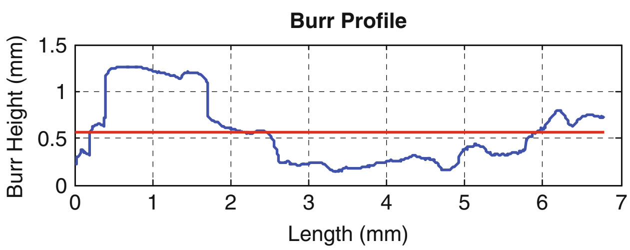

Fig. 4 Measured burr profile [7]

Results

The average burr height measurement values obtained using the image processing and manual methods are given in Table 1 along with the absolute percentage error between the two values with the value obtained using the image processing technique as basis. The results are for a range of 32 work-pieces end-milled under varying conditions of tool angle, depth, feed rate, and speed.

Discussion

The average value was seen as one way to compare the two readings and the comparisons would be different if some other readings were compared. There is a significant percentage error in almost all readings which in some cases

Table 1 Average burr height measurement values for the image processing and manual methods

	Milling conditions				Average burr height (mm)		
Test	Tool angle (°)	Depth (mm)	Feed rate (rev/min)	Speed (rpm)	Manual	Image processing	Absolute error (%)
1	19	0.5	65	320	0.162	0.214	24.2
2	19	0.5	65	410	0.178	0.194	8.3
3	19	0.5	127	600	0.116	0.203	42.7
4	19	0.5	127	865	0.223	0.344	35.2
5	19	1	264	320	0.409	0.549	25.5
6	19	1	264	410	0.329	0.326	1.0
7	19	1	500	600	0.176	0.183	3.6
8	19	1	500	865	0.492	0.553	11.0
9	38	1.5	65	320	0.119	0.536	77.8
10	38	1.5	65	410	0.447	0.331	35.1
11	38	1.5	127	600	2.254	1.527	47.6
12	38	1.5	127	865	2.119	2.058	3.0
13	38	2	264	320	1.399	0.870	60.9
14	38	2	264	410	1.893	1.294	46.3
15	38	2	500	600	3.678	1.561	135.7
16	38	2	500	865	3.629	3.156	15.0
17	55	0.5	65	320	0.815	0.649	25.5
18	55	0.5	65	410	0.435	0.449	3.0
19	55	0.5	127	600	0.335	0.953	64.9
20	55	0.5	127	865	1.178	1.328	11.3
21	55	1	264	320	1.046	0.444	135.5
22	55	1	264	410	1.164	0.505	130.3
23	55	1	500	600	0.633	0.378	67.3
24	55	1	500	865	0.345	0.494	30.1
25	47	1.5	65	320	0.274	0.137	100.7
26	47	1.5	65	410	0.192	0.179	7.4
27	47	1.5	127	600	0.603	0.520	15.9
28	47	1.5	127	865	0.605	0.888	31.9
29	47	2	264	320	0.855	0.427	100.1
30	47	2	264	410	0.737	0.671	9.9
31	47	2	500	600	4.946	2.380	107.8
32	47	2	500	865	1.251	1.423	12.1

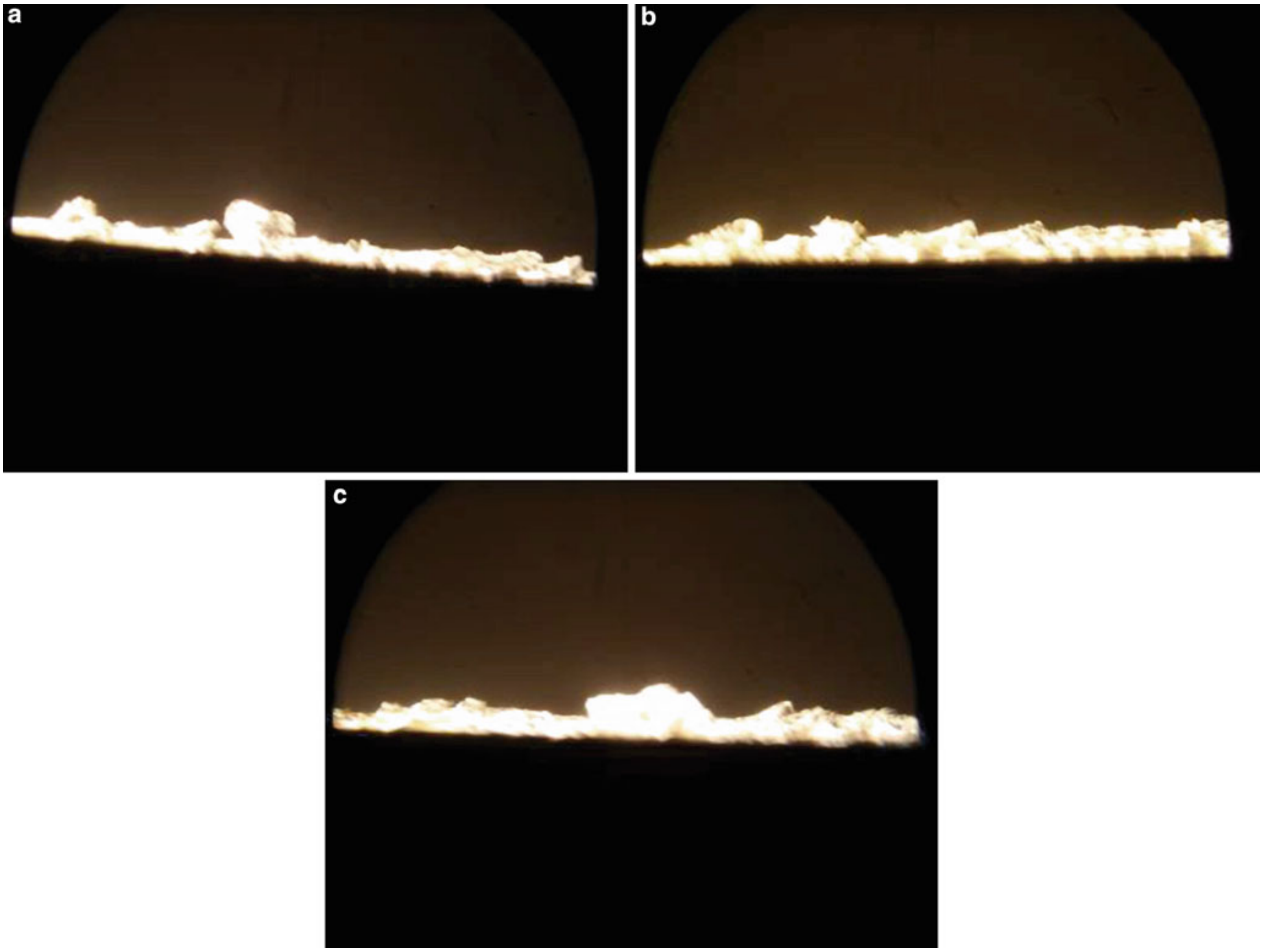

Fig. 5 Images for test 6

exceeds 100 % with an average absolute percentage error of 44.6 %. The values obtained using the image processing method is seen as more accurate since it covers approximately 33 % of the length of the work-piece when compared to the limited number of readings taken using the manual method.

It was also found that generally the error was higher when the burr profile under analysis was irregular. This is evident when looking at the images analyzed for tests 6 and 15 which produce the least and most difference respectively. The three images used for burr height measurement using the image processing technique for test 6 are shown in Fig. 5 and the burr profile is quite uniform with a percentage error of 1.0 %. However, the burr profile is very irregular for the three images shown in Fig. 6 which were used for burr height measurement using the image processing technique for test 15 with a percentage error of 135.7 %.

Although the average burr height is considerably larger for test 15 than test 6, the increase in the difference between the two measurements is difficult to attribute to the increase in burr height. Tests 12 and 16, for example, have greater burr height, using the image processing based results, when compared to test 15 but the error is significantly lower. Similarly, the average burr height for test 25 is lower than that for test 6 but the error is much greater.

Conclusion

While it is obvious that the image processing measurement method will produce more accurate readings of the two methods, the main aim of this work was to compare the results with those obtained using the manual measurement method. It is generally observed that approximating the burr height using the manual method is more inaccurate when the burr profile is irregular. Also, the high error rate with the manual method shows the advantages of the image processing technique which does automatic analysis to a greater extent in a significantly lower time than the traditional method.

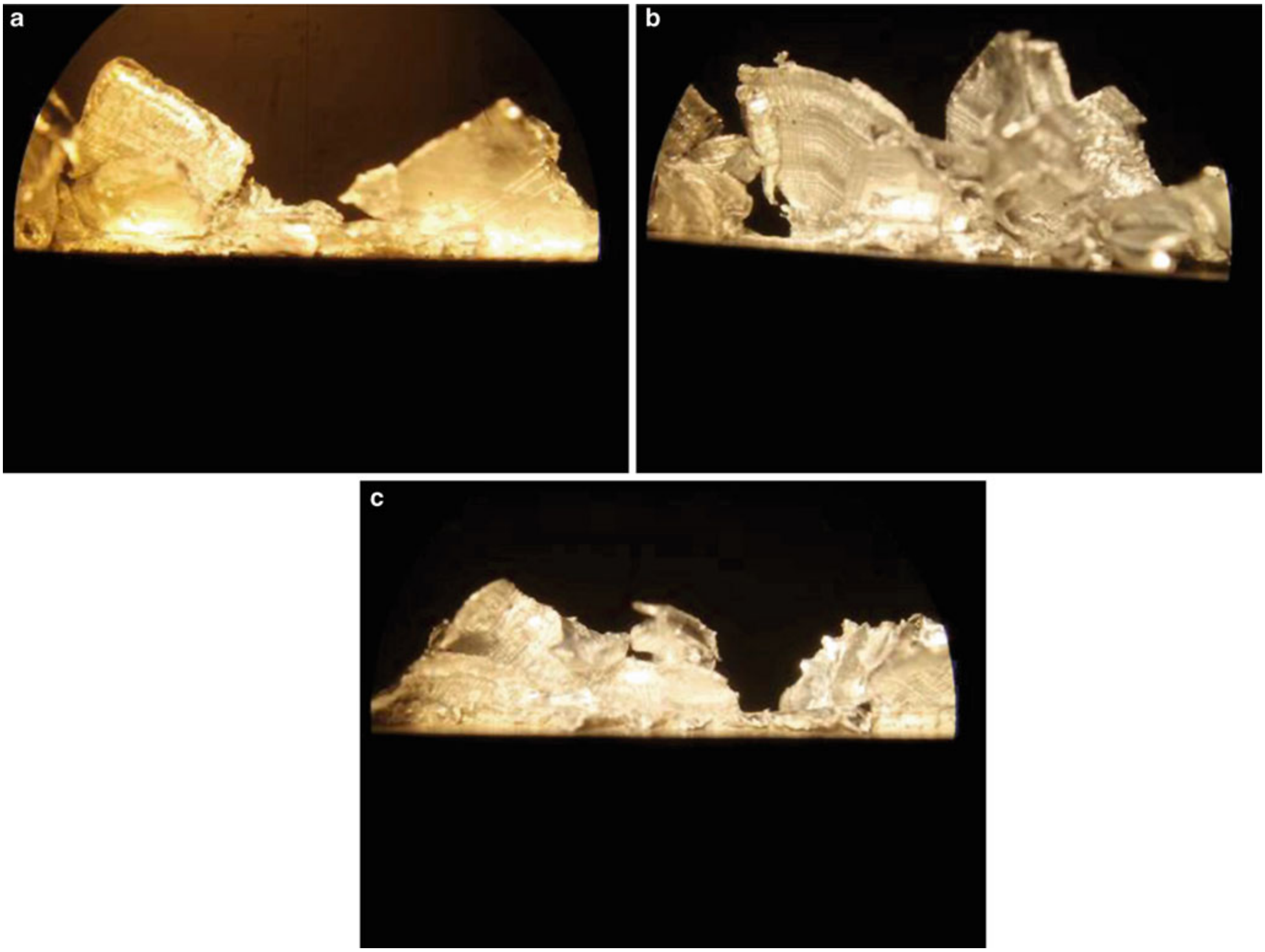

Fig. 6 Images for test 15

The image processing technique utilized here is task specific, low cost and can be implemented quite easily. It could also be adapted for burr measurement in a CAM setup for deburring purposes rather than resorting to costly off-the-shelf products. In addition, a higher resolution digital camera can be utilized to increase the resolution of the image processing technique.

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Automatic Image Annotation for Description of Urban and Outdoor Scenes

Claudia Cruz-Perez, Oleg Starostenko, Vicente Alarcon-Aquino, and Jorge Rodriguez-Asomoza

Abstract

In this paper we present a novel approach for automatic annotation of objects or regions in images based on their color and texture. According to the proposed generalized architecture for automatic generation of image content descriptions the detected regions are labeled by developed cascade SVM-based classifier mapping them to structure that reflects their hierarchical and spatial relation used by text generation engine. For testing the designed system for automatic image annotation around 2,000 images with outdoor-indoor scenes from standard IAPR-TC12 image dataset have been processed obtaining an average precision of classification about 75 % with 94 % of recall. The precision of classification based on color features has been improved up to 15 $\pm$ 5 % after extension of classifier with texture detector based on Gabor filter. The proposed approach has a good compromise between classification precision of regions in images and speed despite used considerable time processing taking up to 1 s per image. The approach may be used as a tool for efficient automatic image understanding and description.

Keywords

Automatic image annotation • Image processing • Color and texture based image feature extraction

Introduction

The overall understanding image content is one of the most challenging tasks in computer vision. In this context, significant advances have been achieved by content-based information retrieval systems, automatic segmentation techniques and automatic image content annotation approaches. So, the large amount of information implicit in the images is getting closer of representations that allow us to develop automatic image description systems.

The problem of automatic image description consists in that: for image the natural language description is required, the generated description should contain specification of objects in images and also the relation that they have with each other defining the meaning of an image [1, 2].

Therefore a generic model for automatic image description has to provide: (1) extraction of image features that allow classification and recognition of objects; (2) representation of features in structures that reflect hierarchical and spatial relation of objects; (3) generation of sentences that describe the content of image by word processing techniques [3]. In this paper we report first two steps required for automatic description of image, particularly indexing the image content based on color and texture.

The proposed approach provides fast global scene categorization by labeling restricted set of objects in image that reflects a real scenario without compromising the accuracy of annotation.

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_20,

The paper is organized as follows. Section "State of Art and the Proposed Architecture" presents an analysis of approaches for automatic image indexing as well as description of proposed architecture and image domain selection. Third section describes the proposed image annotation approach and in fourth section the results of experiments and their evaluation are discussed. Finally, the contributions of the paper are presented in conclusions.

State of Art and the Proposed Architecture

Approaches for Automatic Image Annotation and Description

Multiple approaches for automatic image indexing and description have been proposed. Certainly, one of the first works that address the problem of automatic image description is proposed by Gupta et al. [4] where recognition of people and actions are core elements of description of videos. A set of 39 videos of baseball world series have been subdivided and labeled. Then a correspondence of portion of narrative to specific moment in video is found. Their experiments show a correct assignment of 70 %.

Another work that deals with automatic image description by Yao et al. [5] proposes a general framework that identifies three main stages: (1) feature extraction, (2) representation and (3) text generation. The extracted visual patterns are used for construction of AND-OR graphs (AOG) providing interpretation of content inferred from a picture. Next step is generation of ontology based on AOG converting graph into textual description using RDF (Resource Description Framework) in XML. Recent techniques in semantic Web have shown good results promoting OWL (Web Ontology Language) which seeks to establish them as engine for managing different ontologies.

Similarly, Feng and Lapata proposed a method for automatic caption generation in images from collection of 3.361 news articles from BBC site [6]. Each entry in database consists of a picture, a brief description of story and caption for image. For automatic image annotation they use probabilistic model in which each keyword is composed by set of SIFT descriptors grouped using K-means clustering algorithm. They promote an idea that accompanying text is generated by mixture of topics which can be inferred from concatenation of words and visual features.

While previous approaches provide the analysis of image and related legends that accompany videos or news, DISCO system of Ifeoma and Yingbo addresses the problem of generating short phrases that describe outdoor images considering only processing of images [7]. In the first stage visual content of image is extracted and its description is provided on sentence generation stage. Visual content is analyzed by fusion of information from series of classifiers that seek for predefined objects and scenes in image. Then the image descriptive sentence is generated using obtained categories of scene and objects (regions) of interest.

Kulkarni et al. develop Baby Talk system [8], which uses Conditional Random Field (CRF) as base structure to compute labels for objects in image with information nodes of following types: (1) object or background; (2) nodes with information about object attributes and (3) nodes with information about prepositions (relation) between objects. The object type nodes store object information in categories used by PASCAL 2010 image database. The background detectors are trained by support vector machine that detects sky, road, buildings, trees, water, grass and in this way maximizes the energy function in CRF obtaining the correct labels for each object or background node. Finally, the generation of image description is provided using N-gram language modeling approach based on probability distribution for sequence of words [9]. As evolution of Baby Talk, Kulkarni et al. seek to improve the automatic generation of image descriptions based on visual feature extraction process of triplets (object-attribute-preposition) that encode the relationship between pairs of objects and adjectives that describe them.

Resuming analysis of approaches for automatic image annotation and description the more efficient prototypes are presented in Table 1.

Generalized Architecture for Automatic Image Description

Based on review of well-known approaches in the area we propose a generalized architecture to address the problem of automatic generation of semantic descriptions for images. This architecture consists of three elements: (1) extraction of image and text features; (2) generation of knowledge structures and selection of more significant tuples for indexing and (3) text rendering engine. The block diagram is shown in Fig. 1.

For the first stage we propose methods of textual and visual feature extraction from multimedia document. This process seeks to discretize the majority of information contained therein. This process generally uses an automatic segmentation dividing an image into groups of pixels that share certain visual characteristics. The identified regions are then represented by vectors of attributes, usually color, shape, texture, appearance, among others. Then labeling regions by high-level textual descriptors (i.e. words) is required. This process is known as Automatic Image Annotation (AIA) and has been recognized as one of the main topics of research in multimodal image retrieval.

Table 1 Comparative analysis of systems for automatic image annotation and description

Authors	Test domain	General description	Evaluation and results
Gupta et al. [4]	DVD's baseball games divided into 39 videos with 8,000 images	(1) Low threshold attempt to locate the largest possible number of people; (2) Decomposition of narrative actions; (3) Construction of AND-OR graph: segmented regions are linked to actions [10]	70 % of precision in generation of stories using iterative model
Farhadi et al. [11]	1,000 images, 5 manual labels per image, manual triplets	(1) Image feature extraction: Felzenszwalb detectors, Hoiem classifiers and classifier of scene in general [12]; (2) Generation of triples using MRF; (3) Feature extraction in sentences using Curran and Clark analysis	52 % for Tree-F1 test and 2.33 in range from 1(best) to 3 (poorest)
Feng and Lapata [6]	3,361 tuples (news-image-caption) of BBC	(1) Invariant feature extraction: SIFT descriptors used to discretize image information; (2) Tuple representation using probabilistic distribution of document information, labels and SIFT descriptors; (3) Generation of sentences using automatic generation of titles	Extractive model for grammar (max. 7.0) : assessment of 6.42 and 4.1 for relevance
Kulkarni et al. [8]	847 tuples of PASCAL Data Base	(1) Generation of nodes: detection object/background attributes, 21 elements: color, texture, material, appearance, shape, relations between objects, etc.; (2) Generation of labels that maximize the energy function in CRF; (3) Sentence generation based on probabilistic model of N-grams	(1) description accuracy BLEU metrics = 51 % (2) human evaluation: 3.49 from 4.0
Ifeoma and Yingbo [7]	709 outdoor images: Stanford, Corel, and Google images	(1) Visual content of multiple classifiers: image segmentation and annotation of regions, scene, lightening distribution of objects in layers; (2) Multiple classifiers define labels for each region; (3) Text generation	60.34 % of precision in generation of description

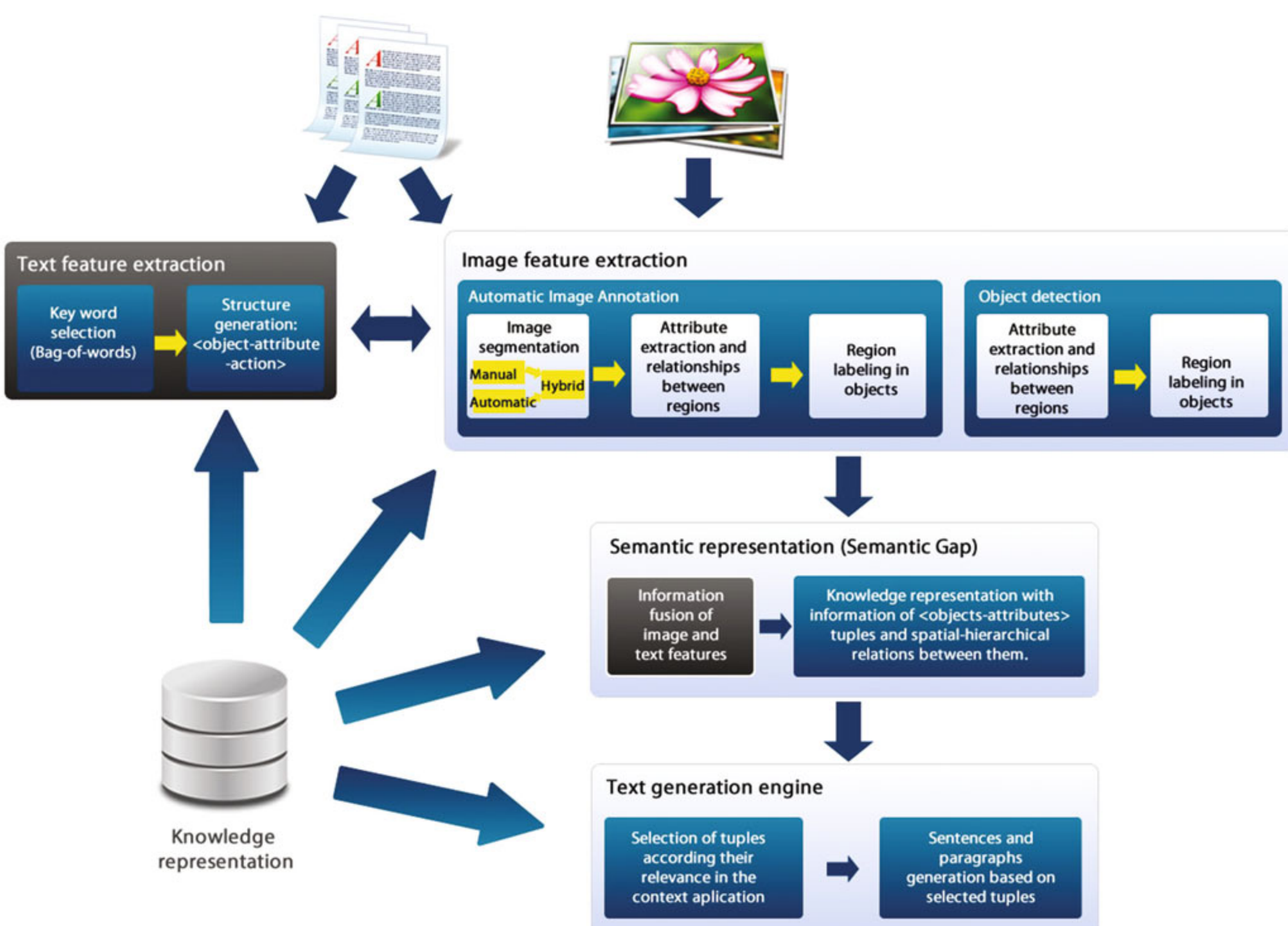

Fig. 1 Generalized architecture for automatic generation of textual description of images

Another module of visual feature extraction that has been integrated to architecture provides Object Detection approach describing an image by objects of interest (region of interest ROI) for example, people or vehicles in a picture. In addition, this approach is accompanied by prediction model of activities which add significant information to text generation engine. While the central part of description is automatic image processing and knowledge extraction, many textual resources attached to images may be useful for improving the results obtained by these methods. Examples of these resources are surrounding texts or captions that describe content of corresponding image.

Because the stage of semantic representation of knowledge operates with textual and visual features, the module for information fusion is required. With tags and attributes of each region the image content is represented that reflects objects, their attributes, hierarchies among them, spatial relationships, etc. However, not all tuples generated by semantic representation module are equally important. Thus, a selection phase of most significant tuples is provided before final generation of image description.

Image Domain Definition for Outdoor and Urban Scenes

As we mention in introduction, the main goal of image understanding is delimiting certain image domains in order to manage the complexity of the task. The efficient classification that covers variety of scenes presented in real-world image databases is a great challenge.

Create a clear and useful categorization of scenes is only a part of it, next one is the definition of hierarchical trees used in automatic image annotation process. For selection of domain we consider the experiences of Xiao et al. for classification of images from Scene Understanding Database that have 899 categories of real-world images [13]. The results they achieved by various feature descriptors such as hog2$\times$2 features extractors, dispersed SIFT descriptors, and histograms of textons reach maximum accuracy of 38 % processing only subset of 397 image categories. Reducing number of image categories to 15 the processing was more specific achieving 88.1 % of accuracy. As result it is recommended to design classifiers for reduced number of categories providing high precision of image recognition [13, 14].

Therefore, we have a question: is there a global scene pre-categorization that reflects real scene without compromising the accuracy of image description and could help us to design a proper approach to resolve the problem of image understanding? As result of analyzing multiple classifications we consider a very general pre-classification covering indoor, outdoor and their mixture—urban images. Selection of this domain allows us to design general strategy for identification of main elements in images and then give their general descriptions.

Proposed Approach for Automatic Image Indexing

Cascade Classifiers for Image Segmentation and Annotation

The outdoor and urban scenes share common elements like sky regions and vegetation areas, but they have some distinctive elements that primary belong to man-made objects. Based on this idea, we propose to perform cascade process for object segmentation and annotation where each cascade step facilitates recognition of regions on the next step. For example, a classifier of the first step searches sky regions and then those regions will be removed from original image. Thus, the next classifier will not consider them for classification of other types of ROI reducing complexity of image processing.

Our main hypothesis is that: for each ROI type there is corresponding classifier. Using classifiers in cascade we may provide labeling of reduced set of pre-classified regions leaving pending the recognition of some not pre-classified objects in image. Despite incomplete recognition, we already will know the main category of analyzed image and we can use specialized object detectors to improve quality of ROI interpretation and labeling.

The proposed cascade classification scheme is shown in Fig. 2, where the original image is used as input for the first classifier. It seeks for sky areas and considers only special image features like certain blue tones and sky texture. This step generates a new image subtracting the sky ROI from original image $I_1 = I_0 - I_{sky}$. This new image is used as input for the next classifier of vegetation regions and so on.

Testing the proposed scheme we observe that the order of classification could affect the performance of whole system. In case of identifying outdoor and urban scenes we notice that the sequence of region classifiers in order: sky, vegetation and water (lake, waterfall, river and ocean) provides enough information to perform acceptable image interpretation.

Image Preprocessing and Feature Extraction

The most important element to decide if we are working with urban or outdoor images is undoubtedly a sky region. For sky classifier we use the proposal of Torralba [15], which suggests that for the detection and recognition of

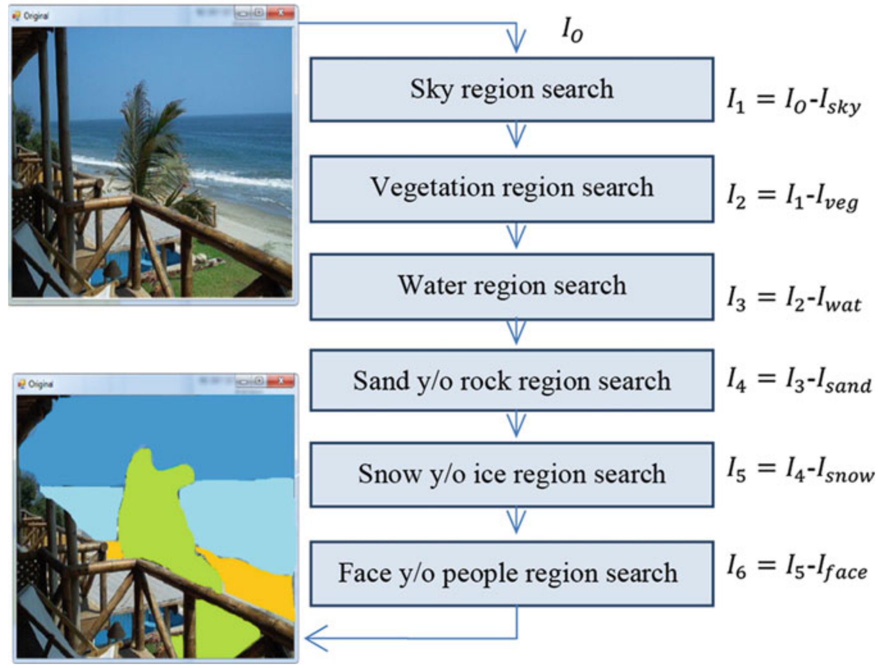

Fig. 2 Basic scheme of cascade classifiers for segmentation and annotation of outdoor and urban images

scenes in images it is not necessary to work with complete image, instead we just need a 32×32 down sample color image.

To improve segmentation stage we use anisotropic diffusion proposed by Perona and Malik [16], that reduces image noise without removing significant parts of image content, typically edges, lines or other details that are important for interpretation of image. With this blur image the segmentation of ROI is performed. However, the algorithm returns many regions and analyzing all of them can be a time consuming process. We opt for analysis strategy based on region occupancy area with respect to whole image. For each region that passes the area threshold we calculate ROI average RGB value. This average color value is classified by a color set which depend on the type of region (scene) that we want to recognize. For example, in the first sky detector we try to classify the corresponding to sky colors in ROI using a set of following colors: white, light blue, dark blue, light gray, dark gray and black.

For color classification we use HSL color model (Hue-Saturation-Luminescence) for simple segmentation of colors. As we know exist around 16, 000, 000 different colors in a 24 bit color image. We train a multiclass Support Vector Machine (SVM) to distinguish color family based on some color samples which may be considered like a possible tones for instance, for sky region. SVM performs classification by constructing an N-dimensional hyperplane that optimally separates data into two categories. The extension of this traditional approach using a one-vs-all or one-vs-one scheme provides powerful supervised learning technique. For this purpose we develop a tool that allow us to select some samples describing, for example sky by natural blue tones. It is also used to pick up samples for other classifiers, such as vegetation, water, etc. An example of regions generated by the proposed tool is shown in Fig. 3.

Region of Interest Detection (Example of Sky Region Recognition)

When a region matches color that may be considered as a sky, the region growing step based on dilation algorithm is applied connecting the smaller neighboring regions which were ignored in the first instance but do have relationship with a sky region. These regions are stored in the vector

$$\overrightarrow{ROIs} = \{r_1, r_2, \ldots r_n | \forall r_i \, in \, Img, \, IsNeighbor(r_i, roi)\},$$

where *Img* is the original image and r_i is a region generated by Perona and Malik anisotropic diffusion clustering. The neighborhood function *IsNeighbor* applies an algorithm of dilation for region of interest *roi* and joins it with the original binary to create an added image. The dilatation is also constraint to join regions that conserve some similarity between r_i and *roi*, so if the region has a light tone it cannot be join with dark color family tones. Then all regions in $\overrightarrow{ROIs}$ and *roi* are joined to generate a new sky candidate (*skyCandidate*). Then a set of spatial-location rules is applied to decide if the *skyCandidate* region could be

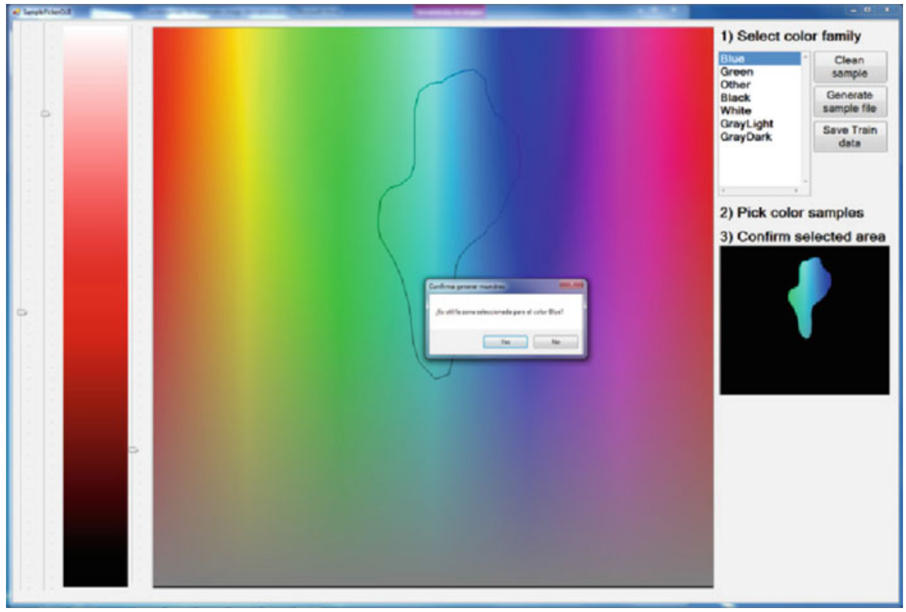

Fig. 3 Generation of color region as a sample for sky classifier

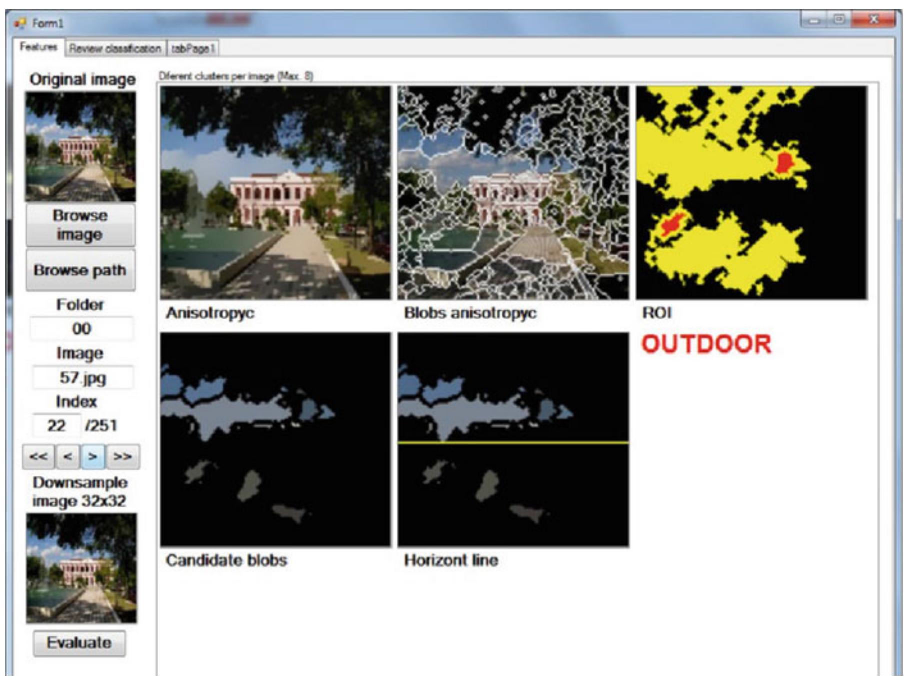

Fig. 4 Correct sky region and horizon line detection

considered as the definitive sky region according to the following criteria:

1. if *skyCandidate*.Top = *Img*.Top and *IsCenterUp* (*CoG*)
2. if *skyCandidate*.Left = *Img*.Left or *skyCandidate*.Right = *Img*.Right and *IsCenterUp* (*CoG*),

where *CoG* is center of gravity of the *skyCandidate* region and *IsCenterUp* function evaluates that *CoG* of region is in the top middle side of the image *Img*.

Finally, for a set of regions $\overrightarrow{ROI\,positive}$ that pass the previous criteria an invisible horizon line *hl* is traced. This horizon line will be calculated with the most great value in the *y*-axis for each r_i in $\overrightarrow{ROI\,positive}$. Thus, all rejected regions by previous condition could be reevaluated and if their center of gravity is over the horizontal line they also will be considered as a sky region. In Figs. 4 and 5 the results of detection of sky region and horizon line are presented. In Fig. 5 the detection of region corresponding to window is interpreted correctly as a sky but definition of horizon line is not acceptable in this scene. In Fig. 6 the indoor image has not sky region, the algorithm fails classifying a sky region.

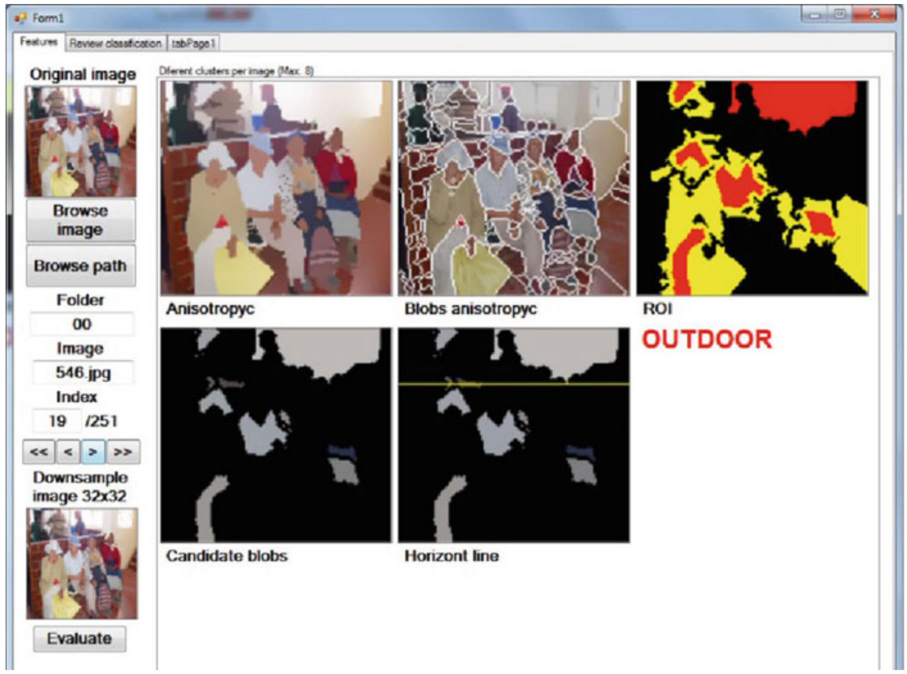

Fig. 5 Sky region detection and incorrect horizon line tracing

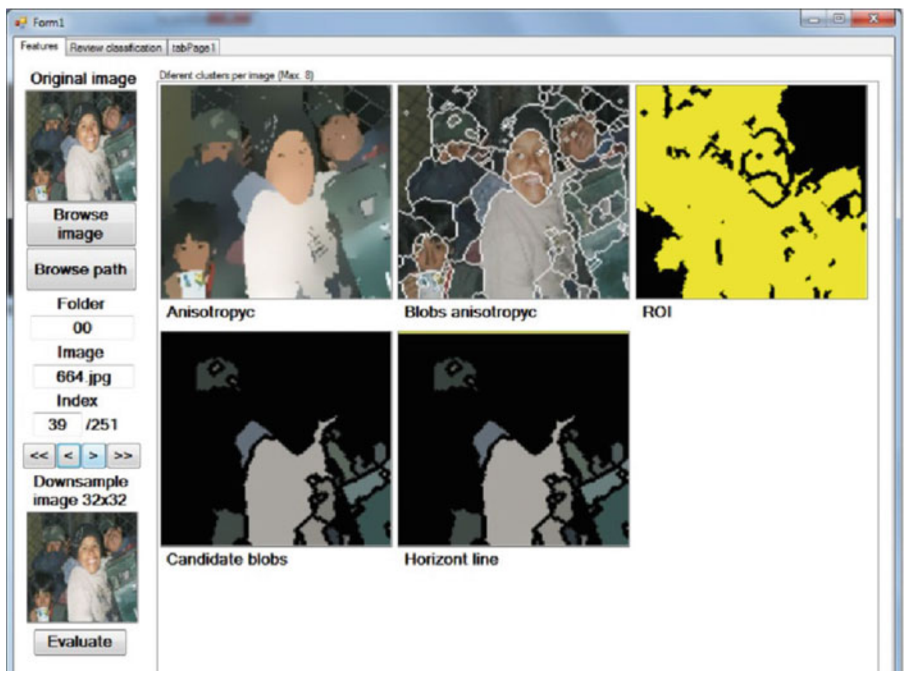

Fig. 6 Classifier fails to detect sky region into indoor image

Results, Evaluation and Discussion

A simple way to evaluate efficiency of the proposed approach is to classify a real-world images dataset identifying if an image belongs to outdoor or indoor scene. For this task we use a subset of IAPR-TC12 image dataset [17]. The IAPR-TC12 dataset is composed by 20, 000 real-world images; each image is manually segmented and annotated using a total vocabulary of 276 labels covering categories such as: Humans, Animals, Food, Landscape, Nature, Man-made objects and other. These annotations give us the option to distinguish if image could be classified as outdoor-urban scene or indoor scene.

When image contains elements such as regions of sky (and its variations), clouds, vegetation areas, mountain elements among others; we label image like outdoor scene otherwise indoor scene. For this task we consider to apply

Table 2 Precision and recall in outdoor-indoor classification task in IAPR-TC12 real-world image data set

	Sky detection in IAPR-TC12				Outdoor vs. indoor	
Folder number	No. of used files in IAPR-TC12	Relevant items in collection	Detected relevant items	Total retrieved items	Precision	Recall
0	251	53	48	67	0.71641791	0.90566038
1	530	211	203	269	0.75464684	0.96208531
2	616	314	297	395	0.751898734	0.94585987
3	545	320	308	382	0.806282723	0.9625
Total	1,942	898	856	1,113	0.757311552	0.94402639

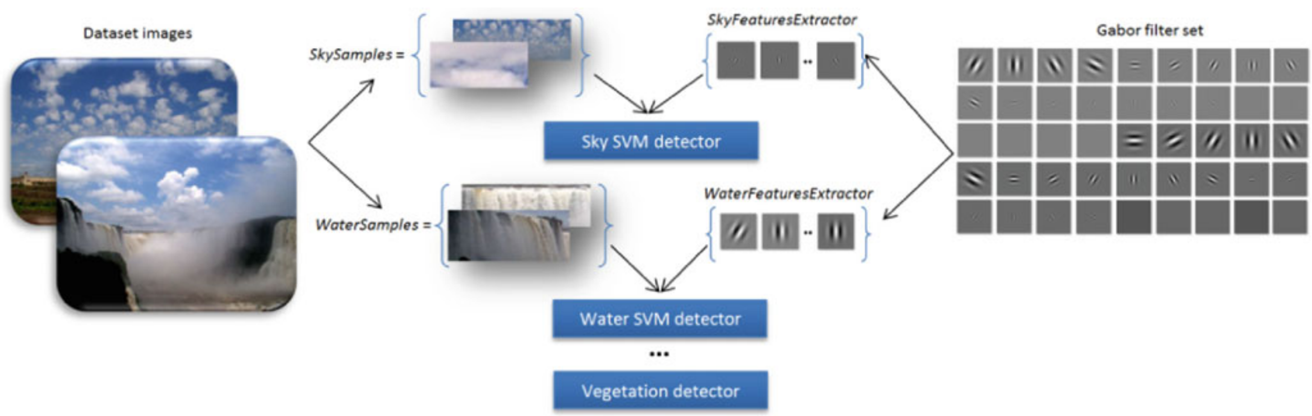

Fig. 7 Approach for processing texture features in SVM-based classifiers

only the sky detector filter of the cascade approach, the hypothesis consists in that: the use of color classification for the regions of interest could properly separate our dataset.

In Table 2 the performance of the proposed approach using different folder of IAPR-TC12 is presented. We evaluate our system with around 2,000 mixed images obtaining an average of 75 % in precision with 94 % of recall. Therefore, using a color as the principal image feature for particular ROI detection the proposed cascade approach precisely classifies outdoor and indoor scenes. However, this result could be improved using analysis of other image features, for example texture.

For this task we opt to work with Gabor filter traditionally used for edge detection. This linear filter has shown efficient results for texture discrimination. Thus, for each detector in our cascade approach, we choose the best feature extractor subset $\vec{FE} = \{f_1, f_2, \ldots, f_n\}$ from n Gabor filter set that classifies better ROI and then each region sample is converted to a feature vector composed by the mean and standard deviation

$$\vec{s} = \{mean_1, std_1, mean_2, std_2 \ldots, mean_n, std_n\}$$

that will be used to train the texture SVM detector. This procedure, particularly for sky and water detectors is illustrated in Fig. 7. In experiments with detectors based on both color and texture image features we obtain increasing classification precision up to 15 ± 5 % without compromising significantly the overall recall of the approach.

The processing speed due to used considerable time-consuming algorithms was low (4 s per image). The performance may be improved significantly using Graphics Processing Unit (GPU) that is frequently used for computationally demanding tasks. For example, low-speed Anisotropic Diffusion Filter implemented in GPU becomes low-time consuming tool making possible to use it in real-time application. For example, in our approach the processing time for each image has been reduced from 4 to less than 1 s.

Conclusion

The proposed approach provides efficient detection and annotation of ROI in outdoor and indoor images based on color features achieving average precision of 75 % with 94 % of recall. Extending cascade classifiers with texture feature detector the precision of classification is incremented up to 15 ± 5 % without compromising significantly the overall recall of the approach that may be considered as significant contributions of this paper. This approach has sufficient merit to be used as a reference in development of applications for automatic image indexing and description.

For automatic generation of image description we apply two approaches: one is based on sentence templates and another exploits ontological descriptions of objects and their relationship [3, 18]. However, the evaluation of text generation engine is considered as a future work.

Acknowledgment This research is sponsored by European Grant #247083: Security, Services, Networking and Performance of Next Generation IP-based Multimedia Wireless Networks and by Mexican National Council of Science and Technology, CONACyT, project #154438.

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Autonomous Mapping and Navigation Through Utilization of Edge-Based Optical Flow and Time-to-Collision

Madhu Krishnan, Mike Wu, Young H. Kang, and Sarah Lee

Abstract

This paper proposes a cost-effective approach to map and navigate an area with only the means of a single, low-resolution camera on a "smart robot," avoiding the cost and unreliability of radar/sonar systems. Implementation is divided into three main parts: object detection, autonomous movement, and mapping by spiraling inwards and using A* Pathfinding algorithm. Object detection is obtained by editing Horn–Schunck's optical flow algorithm to track pixel brightness factors to subsequent frames, producing outward vectors. These vectors are then focused on the objects using Sobel edge detection. Autonomous movement is achieved by finding the focus of expansion from those vectors and calculating time to collisions, which are then used to maneuver. Algorithms are programmed in MATLAB and JAVA, and implemented with LEGO Mindstorm NXT 2.0 robot for real-time testing with a low-resolution video camera. Through numerous trials and diversity of the situations, validity of results is ensured to autonomously navigate and map a room using solely optical inputs.

Keywords

Autonomous Mapping and Navigation • Smart Robot • Horn–Schunck's optical flow algorithm • Sobel edge detection • A* Pathfinding algorithm

Introduction

Unmanned robotics optimizes human time and effort tremendously and effectively has become the epitome of efficient robotics systems. One of the numerous problems autonomous robotics focus on solving is mapping and navigation. People have been trying to utilize the accuracy of robotics to complete such tasks mainly with radar transmission. Efforts with this type of detection have led to successful results advanced as unmanned vehicles that can drive without collision (Guizzo 1). However, many of these methods are unreliable or expensive—unappealing to the general public as well as less developed areas in the world. Specifically, radar-based applications rely solely on emitting waves rendering them susceptible to interference. Radar also cannot take advantage of other multiple data inputs such as color and texture.

Other solutions for the mapping problem such as using the Sharp IR Range finder or Roomba also prove ineffective. The Rangefinder cannot be used by itself with the objective of mapping a room especially due to its thin beam width. The Roomba's method for touching objects to maneuver and store data is even slower and more inefficient for the mapping problem. As the field of automated robotics endeavors to create advanced solutions to more complicated

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_21,

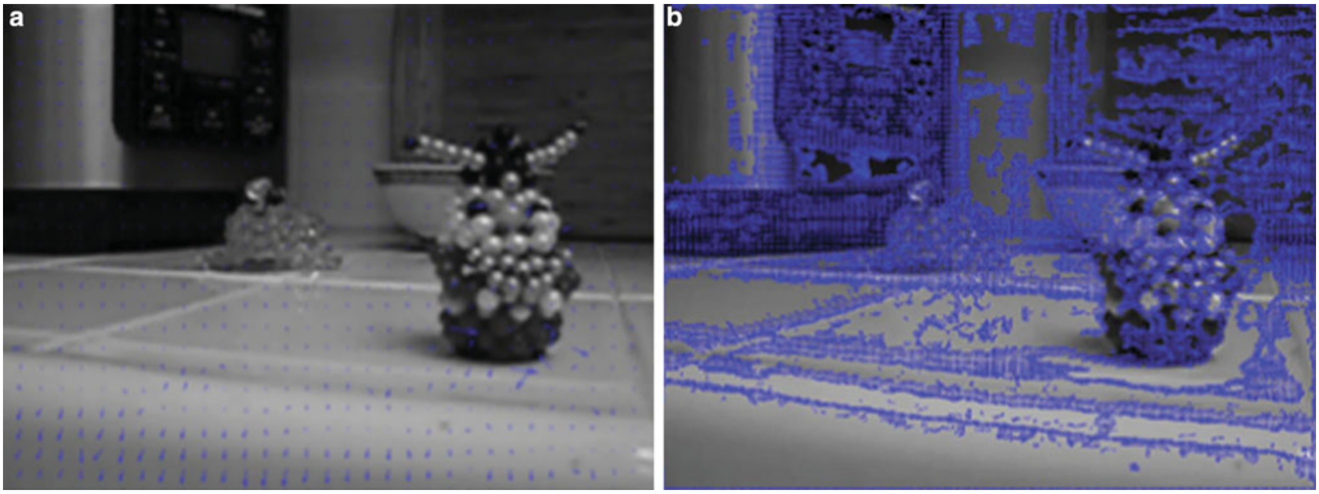

Fig. 1 The edited Horn–Schunck optical flow

issues, equipment that can obtain more information from the external environment becomes more desired.

Thus, this paper proposes an alternative approach to the mapping problem, one that is cost-effective and available to those in less developed countries if needed. Instead of shouldering the heavy cost of radar/sonar systems and equipment, it uses a robot attached to a single, low-resolution camera to obtain more accurate data from the environment and autonomously navigate and map the terrain. Processing vector images, it carries out calculations for object detection through Horn–Schunck optical flow algorithm and responds to those detected objects through time-to-collision induced reactions. The paper endeavors to create a "smart robot" that will respond to any given situation and decide by itself accordingly, creating a much simpler solution to the problem at hand. Through algorithms and video processing (ideally in real-time), the robot travels given the initial direction of the object solely from optical input while avoiding all objects until the arrived goal is reached and a complete map is obtained. The implementation can be split into two main steps: *navigation and mapping*. We first explain the navigation algorithms for object detection and autonomous movement in section "Navigation Algorithms" and then, a map-building method in section "MAP-building Method". Experimental results are given in section "Experimental Results". Finally, concluding remarks are given in section "Conclusion".

Navigation Algorithms

Object Detection

A cheap video camera is used to provide optical input, keeping the end product convenient and more importantly, cost-effective. Then taking black and white converted image frames from the camera, Horn–Schunck optical flow is modified and applied to subsequent frames. The following optical flow equation is used:

$$E = \left[\left(I_x u + I_y \upsilon + I_t\right)^2 + a\left(\left|\left|\nabla u\right|\right|^2 + \left|\left|\nabla \upsilon\right|\right|^2\right)\right] dxdy \quad (1)$$

where α is the constant that controls the smoothness of the pixel movement, I_z is image derivative with respect to z, u and υ stand for the flow vectors. The modified version traces each pixel's specific luminance factor onto the next image frame at time (T + 1) based on image intensity derivatives. The 2D optical flow vectors, u and υ, are then used to calculate pixel motion and generate a gradient of motion vectors between subsequent frames—the vector length representing the distance traveled by the pixel. Figure 1 illustrates the edited Horn–Schunck optical flow. As the object is approached and "grows" bigger, the product of optical flow is a picture with groups of pixels that represent the outward movement of vectors. The high density of flow vectors compensates for missing vectors in homogenous objects since they are made up for by their surrounding pixels. Though Horn–Schunck optical flow does optimize accuracy, however, it becomes difficult to distinguish anything in the field due to the dense optical field in which all the vectors surround both actual objects and the background. Thus edge detection is needed to separate the noise from the objects by distinctly tracing the edges of the objects and ignoring the unimportant details.

Given the plot of optical flow vectors, edge detection altered with the Sobel operator is then applied to the image frame, which outlines objects and simplifies the images. Sobel focuses specifically on the center of the image frame effectively focusing more on immediate objects present in the image frame rather than the background. This function caters to the needs of the robot to quickly and accurately

Fig. 2 Sobel edge detection and enhancement for the visibility

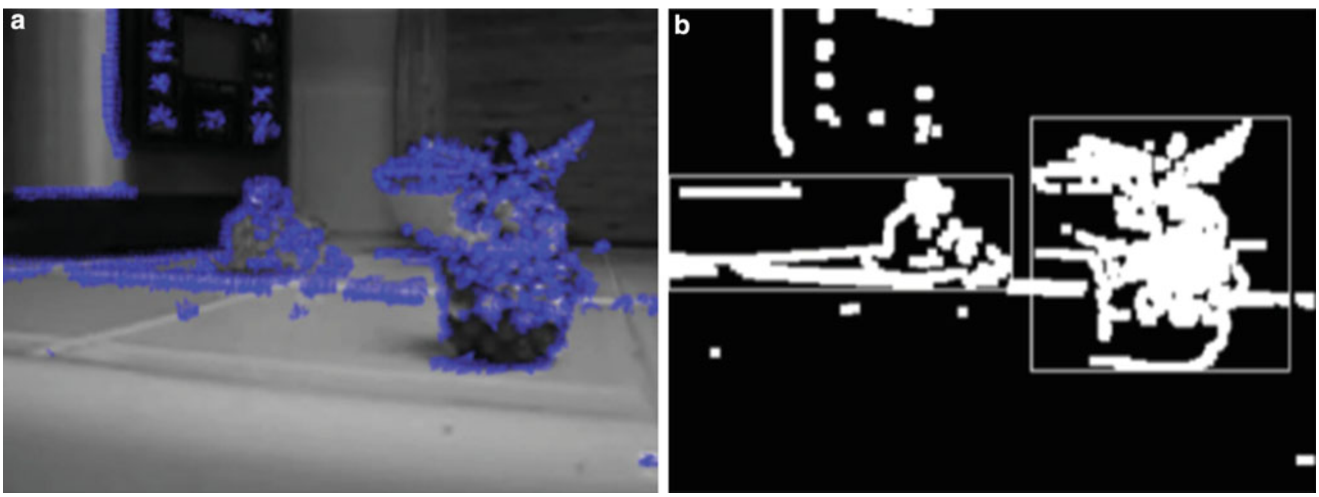

Fig. 3 Edge detection algorithms: Illustration (**a**) The vector-tracing algorithm (**b**) The box-blobbing algorithm

identify objects to avoid. The actual edges are then widened by 10 pixels, functioning as a "bolding" action (see Fig. 2). The purpose of these procedures is not only to make the objects more noticeable with wider edges, but also to lay down the foundations for the next progression of noise minimization: vector clusters.

After bolding object edges, a vector-edge tracing algorithm overlaid the optical flow vectors onto the edge-detected frames. As a result, only the vectors lying inside the 10 pixel width outlines were shown (see Fig. 3a). The fusion creates distinct blobs of vectors most likely to be associated with objects as the Sobel and tracing algorithm ignores the background. Because the clumps of flow are certain pixels away from each other, it becomes possible to define distinct blobs in comparison to one conjoined cluster. A blob-boxing algorithm is then used to separate the vector clusters with boxes based on an 80 % overlap threshold (see Fig. 3b). With this algorithm, the number and relative column locations of the objects in the image frame can then be extracted. Thus, this code effectively minimizes the processing of distracting details while the general image of the object stays intact. Overall this method increases productivity of optical flow since the motion vectors now focus only on the objects in an organized fashion.

Autonomous Movement

The blob-boxing algorithm essentially provides information to calculate Focus of Expansion (FOE), a crucial input needed to ultimately find time-to-collision. FOE is the source of vector expansion as the video camera moves closer to an object (Fig. 3). As mentioned previously during optical flow, as the object grows, the optical flow motion vectors

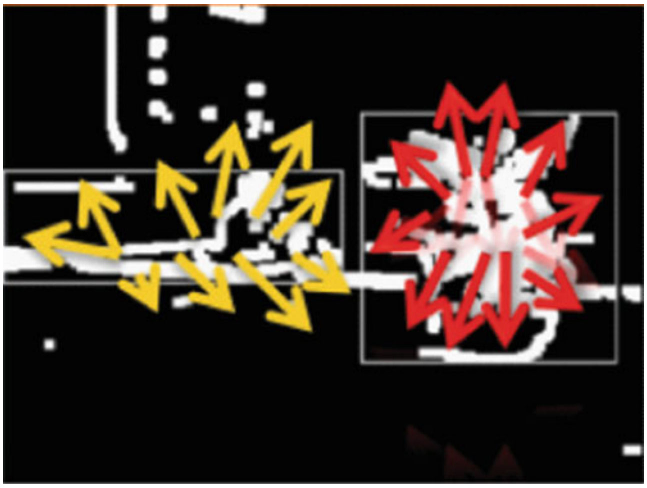

Fig. 4 Box frames to calculate the multiple FOE's

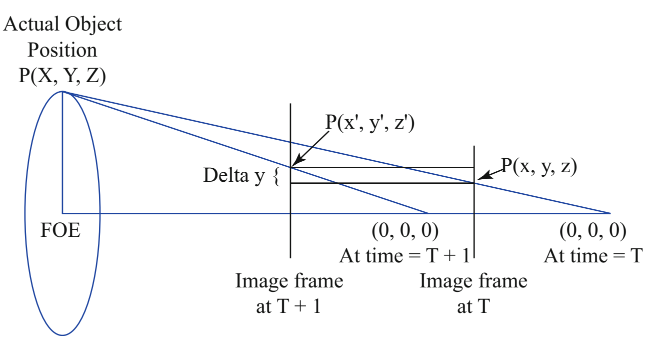

Fig. 5 Time-to-collision's use of comparing equilateral triangles

expand outwards. FOE is the origin of those vectors. However, because of the possibility of multiple objects in one image frame, the boxes created in the blob-boxing algorithm become separate images frames from which FOE can be calculated individually. So with multiple objects, the vectors specific to each individual object in its own respective "box frame" are averaged to calculate numerous focuses of expansion (Fig. 4). These values are crucial as variable y and dy in time-to-collision calculations as dy is the change in distance from FOE per frame change and y is the vertical distance from FOE.

The time-to-collision (TTC) code is the core algorithm that allows the robot to move autonomously using only optical inputs. It calculates the distance in frames until collision with a stationary/moving object at a specific time without knowing the robot's speed; it does not calculate real measurements but enough for relative comparison. Referring to Fig. 5, the equation for time-to-collision is a comparison of equilateral triangles: $y/z = Y/Z$. Though z actually depends on camera specifications, it is assumed as 1. The origin lies on the z-axis, and x and y are based on pixel "p". $P(X, Y, Z)$ is the coordinate of Focus of Expansion (FOE), the origin of the vectors, but it remains unknown since it is the coordinates of the actual image.

Since $z = 1$, the equation turns into $y = Y/Z$. Taking a derivative with respect to time yields the following equation:

$$\frac{dy}{dt} = \frac{1}{Z} \cdot \frac{dY}{dt} - \frac{Y}{Z^2} \cdot \frac{dZ}{dt} \tag{2}$$

Assuming that $P(X, Y, Z)$ is stationary, dY/dt in (2) can equal 0, allowing for Y to be substituted by yZ. Then, the result is as follows:

$$\frac{dy}{dt} = -\frac{y}{Z} \cdot \frac{dZ}{dt} \tag{3}$$

The last step involves dividing both sides in (3) by y and taking the reciprocal, which finally leads to the following equation for time-to-collision:

$$y \cdot \frac{1}{\frac{dy}{dt}} = -Z \cdot \frac{1}{\frac{dZ}{dt}} \tag{4}$$

Since dy (change in distance from FOE per frame change) is known, dy/dt in (4) can be found by comparing the pixel vertical movement of two frames, resulting in a ratio that should equal the negative of the actual movement on the Z-axis. So finally accumulating all the information from the previous codes, the focus of expansion (FOE) can find the time-to-collision—more importantly, without any distance or speed information. Rather, for the whole process, only two points are needed, making this algorithm remarkably efficient especially when installed in a reaction system. All these calculations are verified and simulated with MATLAB.

Cumulating all the above source codes, specific hardware for robot real-time testing was created. The robot was made from LEGO Mindstorm NXT 2.0 robot with a low-resolution video camera. Because the robot was programmed with Lejos in Java, a portal was needed to pass MATLAB time-to-collision calculations to Java. Thus, the time-to-collision information was transformed into a bar graph; essentially the image frame was split into 5 bars (vertical regions), each containing object(s). Then the height of the bars represents the time-to-collision (lowest) of objects in that bar space (Fig. 11). Each column would have time-to-collision calculated which then influences the heading angle to react to the certain time-to-collision.

First, a threshold was made: time-to-collision values greater than 300 frames were taken away because there was no need to sacrifice TTC running time on non-immediate situations. Next different types of reaction situations were analyzed. For example, there could be 5 bars meaning is an object with a valid time-to-collision in each of the bars. However, there also could be different combinations of 4, 3, 2, and 1 bar(s) that could be passed to the Java compiler. Thus three types were generalized.

The first type, given 5 or any combination of 4 or 3 bars, moved the robot from that object at relatively large header angle fluctuations. The header angle changes 10° every time for 5 bars, 8° for 4 bars and 6°–7° for 3 bars. The direction of change was set to clockwise unless otherwise specified. This given statement is overridden by the actual place of the bars. For example, if there were 3 bars located at the left 3 bars of the 5, then it is more logical to move to the right. Such adjustments were made. The second type, given 1 or 2 bars that are close to each other, moved the robot away from those bars (again clockwise or counterclockwise based on location of the bar) at 5° of header angle change per analysis. The third situation was when the bars are split. If 4 bars were split into 2 and 2 it was not enough room for the robot to go in between, so it defaulted to the first situation. However, if there existed 2 bars split into1 and 1, then the robot was allowed to try and maneuver around it first.

In each trial, the bounding box and time-to-collision algorithms were checked if they were operating in real life. The robot was first set to stand still as time-to-collision calculations were made, allowing for the bounding box to separate objects from the background while the TTC number remained around 400. This served as a control. From there, the algorithm was testing in three different ways. In the first situation, the robot was allowed to roam randomly with stationary boxes/objects. The second situation had the robot turn away from objects in order to follow a path towards a set destination. The third way ensured that the program was not case-specific or "pre-programmed" and consisted of placing boxes in front of the robot and observing its reactions.

MAP-Building Method

At this point, only a random and vague reaction system is developed. So after establishing autonomous movement from the time-to-collision algorithm, a systematic method of movement is needed to achieve the ultimate goal of mapping a blueprint. The mapping algorithms first creates a pseudo-infinite grid, a 999 × 999 matrix of zeros since the room size would be unknown (each unit length representing the robot's length). Then it positions the robot virtually in the center of the grid at (500,500), so that it can proceed to any direction of the grid regardless of which corner the robot began from physically in the room. From there, the robot is programmed to turn 90° counterclockwise, moving a set value x to be used for time-to-collision. If the time-to-collision becomes less than alpha 100 frames, then an object are assumed to be on the next point, triggering the robot to move back by the set value x to the center of the original point. This process run in a loop until the robot finally saw an empty spot allowing it to proceed to the next grid square. However, note that this procedure to move is only observed in the first part of mapping: detecting walls (as described next). To keep track of the robot's position virtually in a grid-representing matrix, numbers are used to represent the status of each coordinate: 0 is an unknown spot, 1 is a visited spot, 2 is an object, 3 is part of a wall, and 5 is an inaccessible coordinate.

With this, first the robot is programmed to go around the room once using the moving procedure described above. It will stay on the periphery to detect the positions of the walls. The number 4 is used virtually to mark the initial position of the round, to notify the robot when it made a complete round in the actual room. After all the walls are detected, a resizeGrid function then fits the grid into a more appropriate matrix by finding the smallest and greatest row and column values in which 3's are present. This cut down inefficiencies since it is unnecessary for the robot to consider the entire pseudo-infinite matrix for every situation as most of the indices will be 0.

After the grid is resized and the initial 4 reached, the robot is then prompted to find a virtual ideal path around the room using the knowledge it has of the room so far: the walls. The purpose of the ideal path is only to guide the robot in a much more efficient manner as it would then be able to reference the ideal path as an original path while compensating for objects in the real environment. This is done in a separate virtual grid to not affect the grid the robot would actually map; the real grid is kept the same as before the ideal path process begins. The ideal path is made in a spiraling fashion as there will be almost no overlaps of 1's (visited spots) in an ideal setting. To do this, the virtual robot is programmed to continuously "hug the wall" using a virtual wall as reference. So, much like the code that finds walls, the ideal path algorithm also marks the beginning position of the round as a 4. It then marks the visited spots as 1's as the virtual robot makes its first round in the grid. Once the initial 4 is reached again, the ideal path algorithm then changes all the 1's and 4's recorded to 3's, thus creating a virtual wall within the separate virtual grid. With the virtual wall established, the virtual robot can then repeat the process using it as reference again to make another round until the whole room is covered. These points are stored in order in a list to be used when the physical robot begins to make rounds.

To avoid the virtual robot trapping itself in the starting corner when it comes back to the initial 4 position, a calculation is set to move the virtual robot to the nearest zero. It calculates the Euclidean distances to the closest zeros (unvisited spots), moves the virtual robot to the smallest distance, and continues to find ideal path. Though moved, the virtual robot's direction is kept same since it defaults to the original one to continue the process. The ideal path is finished when the virtual robot is fully trapped in the middle and the closest zero is at a distance significantly far away, indicating that the zero is inaccessible and outside of the room. It also shows that the virtual robot has been on every single possible position in the separate virtual grid.

Once the ideal path is found, the physical robot could now make its rounds following the original ideal path. In this portion, the robot does not move as described when it finds the walls originally. Instead, it adheres to the ideal path, only to deviate when an object is detected through time-to-collision. Only positions that have value 0 are visited to make the mapping efficient as possible. As obstacles are detected along the way, the robot uses A* Pathfinding algorithm to give the shortest path between two points avoiding objects. However, because not all objects are known, the algorithm is used continuously as the robot moves and continues to encounter objects much like the functions of a GPS.

Experimental Results

The current experiments itself are the building and design of an autonomous robot, so the results naturally are measured through the accuracy of the robot's codes and instructions. Thus, the analysis of the algorithms is observed by the robot's ability to avoid objects; if it is successful in this endeavor, then this related that the time-to-collision calculations are working and in cascade, the object detection codes as well. TTC values are also printed for a more precise understanding of what happened in the trials.

The nature of the results were recorded and observed in 9 trials, 3 trials for each of the 3 situations described in the Methods section. First, the control was established to make sure that the time-to-collision was accurate and consistent. While the robot was held by the wheels (so no movement) the time-to-collision kept at a consistent range from 380 to 490. The values were mainly about 440, 443, 450, 451, 446 etc. This proved that the little fluctuations were due to light and that the relative time-to-collision seems to be working properly. When the robot was let go after the control results, the time-to-collision dropped considerably to 70 as there was a washing machine in front of it. Testing the following trials was done in a garage.

In the first type of situation, the robot was left to roam the room for itself with a random pathway. The time-to-collision values printed were all over the place since there were multiple objects in the image frame that the robot had to detect and turn away from. Refer to the measurement results in Fig. 6 in which the elapsed time is the time taken to calculate/process the time-to-collision value, the TTC value is the number of frames before the robot will hit the object, the column number refers to the location of that object, and the heading angle change relates to its specific

```
Elapsed time is 0.972144 seconds.
TTC: 70.1227
Column Number: 2
Heading Angle Change: 10

Elapsed time is 0.374341 seconds.
TTC: 17.1003
Column Number: 2
Heading Angle Change: 40

Elapsed time is 0.878175 seconds.
TTC: 10.5562
Column Number: 2
Heading Angle Change: 40

Elapsed time is 0.469931 seconds.
TTC: 102.0256
Column Number: 2

Elapsed time is 0.387387 seconds.
TTC: 32.0021
Column Number: 2
Heading Angle Change: 30
```

Fig. 6 Illustrative measurement

TTC value. Since the elapsed time is below 1 s, it indicates that the TTC calculations are pretty much in real time. They jumped from low to high values unexpectedly, as the robot would turn into empty spaces, these fluctuations occurring in a random cycle. Consequently, the time-to-collision values reflected the random nature of these trials. However, though "random", the trials proved the algorithms to be quite robust in its ability to avoid objects. Surprisingly, there were no crashes until the very end of trial 3. In the first two trials, the robot successfully started, stopped, and turned with respective header angles. In the trial 3 crash, however, the robot turned and hit an object that was not in its image frame, but rather in the swing of its header angle. Though it indicated partial failure in these trials, in the context of mapping, these random movements would not exist but rather be replaced with systematic movement across the grid. Thus, this crash is not deemed significant given the overall context.

In the second type of situation, the TTC values were in a more consistent pattern since the robot was bounded by boxes to direct the robot towards a specific destination on a path. The robot successfully passed all trials without hitting any of the boxes and was able to "bounce off" of all the obstacles to finally make it to the end of the garage. The process, however, was painfully slow and inefficient, because at that stage the robot had only a random/vague reaction system (not systematic like in mapping). But it is important to note that these trials were mainly to test the TTC accuracy and if application was even possible.

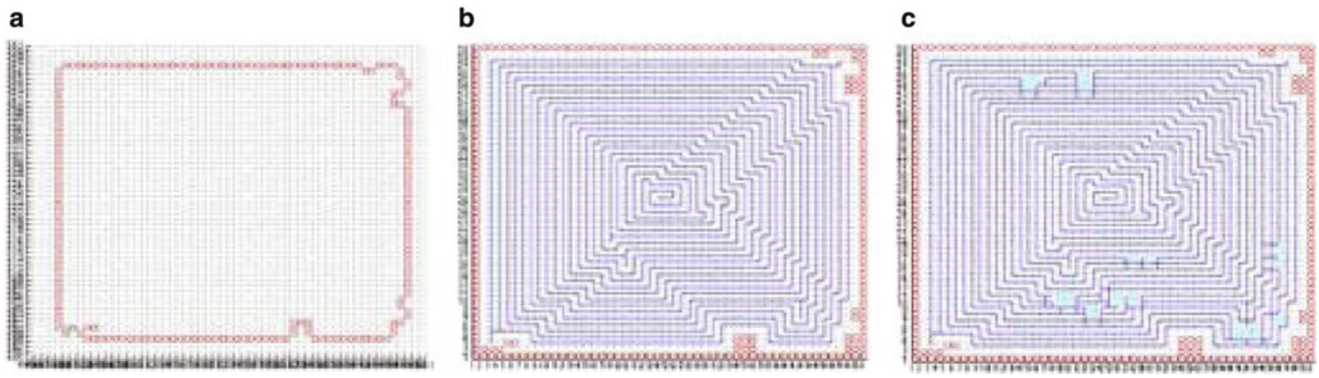

Fig. 7 Virtual progression of the mapping procedures in a relatively large grid

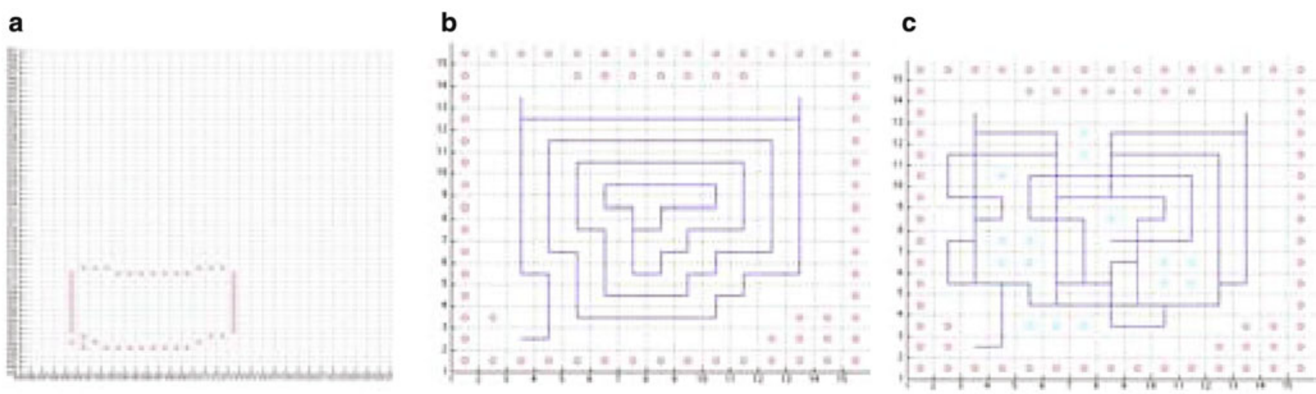

Fig. 8 Virtual progression of the mapping procedures at a more realistic size of 15 × 15 (units are in the robot's length)

The third situation was probably the most exciting since it involved sporadically placing objects in front of the robot and observing its reactions. In all three trials under this condition, the robot successfully avoided all obstacles even if objects were immediately placed in front of it again after turning. This proved that the program was not preprogrammed, but rather could respond to various situations. The significance of this flexibility is immense since the whole point was to build a code and robot that could "think" for itself as a smart robot. Noting that in all situations, time-to-collision was accurate enough for the robot to avoid objects, it proves the TTC and all the object detection algorithms to be robust and able to be used in a broad spectrum of applications.

The mapping portion was also found to be successful in finding a systematic way to map a room with most efficiency. A virtual space was used to test our algorithms with many trials. Results were printed out on a grid using different colored circles to mark walls or objects and lines to show ideal and robot paths (see Fig. 7). For Figs. 7, 8, and 9, in part (a), the wall finding algorithm is finished and in part (b), the grid is resized to the size of that room. The ideal path is drawn as shown and then in part (c), the virtual robot successfully detected objects and avoided them, ending in the middle of the room.

First, the wall-mapping algorithm that finds walls and boundaries of the room ran smoothly with no kinks after debugging. The moving method used to initially find walls worked well in the virtual setting (though in real life, that is still to be tested for certainty). The advantage to virtual testing was that many trials could be run in relatively short time. With this, complete accuracy and full execution of the wall finding code was confirmed with 20–25 successful trials of this individual code (Fig. 8a). The cutting grid algorithm worked flawlessly as well for its numerous trials. Regardless of size, big (50 × 50) or small (11 × 15), or random shape the room was made into, the algorithm was able to successfully cut the excess units in the grid and fill in gaps on the outside with extra number threes to indicate those units are part of a wall and not inaccessible zeros (Fig. 8b). The product of the resizeGrid algorithm can be seen with the ideal path pictures in Figs. 7b, 8b, and 9b.

The ideal path algorithm also proved to be robust to all different types of grids: square, rectangle, big, small, some

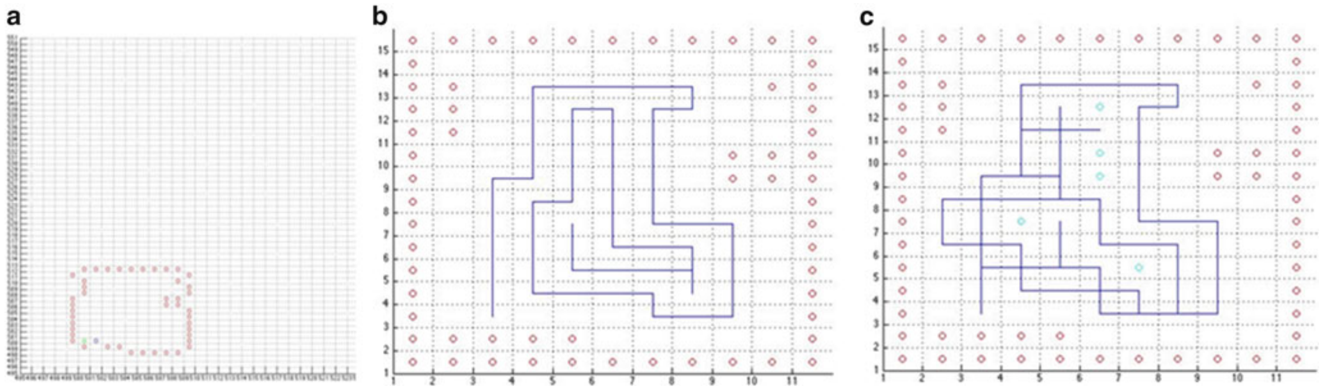

Fig. 9 Virtual progression of the mapping procedures with a rectangular room of 11 × 10 deeming more realistic to real life situations

with irregular walls. Though, at first, the code broke when the robot was trapped at the end of each spiral around the room, this was later fixed as stated in Methods by calculating the closest zero and moving to it. After this alteration, the entire code ran smoothly for all time. However, though these algorithms ran flawlessly, once the virtual robot began to actually map, complications rose up. First, sometimes the A* Pathfinder gave longer paths, reducing the optimal efficiency of the mapping process expected. It was also found that for some odd reason, the entire code just broke and produced unreadable grids with awry paths. However, with careful analysis, it was found that it was not our codes specifically that caused this, but the addition of the A* Pathfinding code. Our analysis stopped here as we did not understand the A* code, preventing fixes, but for many cases the virtual mapping did in fact work (Fig. 9c).

Overall, the virtual trials for mapping confirmed that the codes were robust and working well enough to be implemented in real life in combination with object detection and TTC codes.

Conclusion

The current work has shown that it is indeed possible to autonomously navigate and map a room using solely optical inputs. The various elements for implementation, including object detection, time-to-collision, and the mapping codes, have been proved to be robust in their flexibility and accuracy passing numerous trials and various situations. This opens the door to the idea that our codes and methods can be used for a broad number of other applications beyond mapping such as autonomous vehicles or exploration robots while staying cost-effective and completely reliable.

The validity of the conclusions come from the sheer number of trials ran and the diversity of the situations that were tested, proving the continuity and thus, validity of the results. The continuous success of the TTC trials reflect that all codes leading up to object detection worked and the time-to-collision calculations were accurate in avoiding crashes. Likewise, the near total success of the many mapping trials also show validity of the results produced.

To improve, future work towards the possibility of developing a unique path finding algorithm that optimizes for this work's blueprint robot. Furthermore, another type of robot can be designed to systematically map and maneuver using time-to-collision. However, because the time-to-collision measurements are only estimates, it is predicted that the actual robot movements will lack precision and not be consistent since they are reliant on the TTC values. This would lead to faulty communication between the positioning in the grid and the real room.

Differentiation between walls and objects is also another future experiment that must be looked into. In a standard indoor setting, objects will most likely be placed on the walls and to increase the usefulness and accuracy of mapping a blueprint, a robot would need to detect the differences. This can be achieved with the use of RGB gradients and comparing sharp changes between color values combined with the use of Sobel edge detection to perhaps detect texture as well. Thresholds would be found during experimentation to fine tune the color detection especially when both the wall and object are similar colors. In the far future, object identification can be added on to object recognition. This could be achieved through perhaps a database of classifications made experimentally that narrow down objects to their identification. This would be the ultimate goal of the blueprint problem.

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NS2IT: Simplification of Computer Network Simulation

Martin Nagy and Peter Magula

Abstract

Nowadays, Internet applications generate more and more communication traffic that needs to be wisely handled by computer networks. Therefore there is a big demand on communication protocols to have less payload and bigger efficiency. In this paper, we briefly explain our solution of enhanced simulation and visualization of network protocols based on ns-2 simulator, called NS2IT. Our goal is to simplify the simulation's process, data visualization and measurements' comparison. Proposed prototype teaches students about characteristics of given protocols and informs developers about protocols' performance in specific network situations. All these information are presented by rich web interface.

Keywords

Component • Network simulation • ns-2 • Network simulator

Introduction

Nowadays, the simulation of computer networks is becoming a rather difficult and complex task to accomplish. Because of the large amount of accessible technologies, billions of possible communicating couples, the large scale and complexity of the networks, the computer network simulations tend to produce large amount of data, which is almost impossible to interpret correctly in a reasonable amount of time. Similarly, a programmer has to be rather experienced when he/she wants to create a fully operable input file for the most used simulation tools. In this paper, we introduce the reader to the area of computer networks simulation, to the means by which various types of simulation can be achieved and how can we correctly and efficiently interpret the large amount of simulation output data with proposed solution.

Our goal is to develop a simplified process of network simulation in its whole lifecycle, from designing a network, simulating it and finally, correctly interpreting the output of the simulation with a focus on those aspects and values of the simulated network that are in the user's interest. Our project is aimed at one of the most known computer network simulators called ns-2. We briefly explain the characteristics and the comparison of ns-2 and ns-3, along with the types of computer networks that can be simulated with these simulators. We also introduce our solution that simplifies the usage of the ns-2 simulator by adding an easy-to-use input and output interface to this simulator. We also offer a concept of simulating networks over the Internet as a server side application with a simple, yet powerful web interface that provides a high portability and accessibility to our solution with only minimal scripting or programming knowledge requirements on the user.

Our solution is a very agreeable way to bring the network simulation capabilities of the complex and powerful ns-2 simulator to inexperienced users, without demanding a profound knowledge of either programming skills needed to create a fully operable input simulation file, or a good scripting knowledge, that is required to parse the large amounts of the output data, that the simulation creates. Our solution provides both of these capabilities in a neat and friendly way.

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_22,

Related Work

The main goal, as it was mentioned in previous section, was to simplify the network simulation as much as possible. This included everything from scenario creation to the analysis of the outputs. We wanted to focus on the wireless networks because they have become more and more popular and a proper understanding of wireless technologies would be essential to the future students of computer networks. We wanted to use existing tools to make our project even better.

We had to choose which network simulator fits best our needs. It is clear that a commercial simulator is not a way to go. Basically, there were two options: network simulator 2 (ns-2) and network simulator 3 (ns-3) that are both available under GNU GPL license. Since the simulator is meant to be the core of our solution, we had to make proper choice regarding both simulators' characteristics, input and output formats and supported protocols.

Ns-2 is old and stable simulator. Its development started at Berkeley University in 1996. It runs on Unix-based systems and the core is written in C++. Simulation scenarios are written in OTCL (Object Tool Command Language). The reason why two languages are used is that writing code in C++ requires a lot of time, debugging, etc. But creating scenarios requires an agile way of writing code, so OTCL (also referred simply as TCL) is used here [1, 2, 10].

On the other hand, we have ns-3, a fresh new simulator. Development of this simulator has started because ns-2 was technically old and the architecture was not designed to offer easy extension of simulator core. Despite its similar name with ns-2, it is coded from scratch. Ns-3 core is written in C++ and simulation scenarios can be written in C++ or Python. Here, we can find a similar approach where a scripting language is used to create simulation scenarios [2, 9].

The difference between ns-2 and ns-3, considering the wireless networks, is that ns-2 did not support wireless network simulations in its first versions. This functionality was added later. Ns-3 has had this functionality from the beginning, moreover, it was one of the ns-3 authors' goals to focus on wireless networks and simplify simulations of wireless networks. This means that wired and wireless simulations are very similar when writing scenario in ns-3. However, this attribute is not very important for our project because users will not have to write a scenario, they will use our comfortable graphical interface. A very big advantage of ns-2 is its protocol support. It has many protocols implemented in simulation core, plus there is a huge community of users who have created a lot of extensions.

To sum it up, we identified the main advantages and disadvantages of each simulator [8, 11, 4, 5–7]:

Ns-2

- Advantages
  - Stability
  - Many extensions and tools available from community
  - Many protocols supported
- Disadvantages
  - Old core architecture
  - Different scenarios for wireless and wired networks

Ns-3

- Advantages
  - Easy extensible architecture
- Disadvantages
  - New simulator, many bugs are not fixed
  - Number of supported protocols is low
  - Lack of properly tested protocols

Finally, we decided to use the ns-2 simulator. The main reason was its stability and the number of supported protocols. In the next years, ns-3 will become a powerful tool with easy extensible architecture but now it just suffers from lack of properly verified protocols [3].

NS2IT Overview

NS2IT is a solution that makes your network simulations as easy as they can be. It consists of four main modules which are connected together as displayed in Fig. 1.

The first module is called Simulation design. It is the very first module which interacts with the user. In simulation design module, user can create his own network topology with Topology editor and Traffic editor tools. Topology editor is used to define which and how many elements will the network have. In this case, user has to create also traffic between these network elements, what can be achieved with Traffic editor. It is very important to know what network's behaviour we want to simulate. Then, we can set up traffic properly. When everything is properly set up, module called Autogenerator will create TCL script, which is output of Simulation design module.

Simulation design module offers also another option. User can pick the network topology from our database of predefined and saved topologies. This is a more simple way. It can be used when user does not know how to set up the topology and traffic. Also, it can be used to recreate previous simulation topology with new traffic and re-run simulation again.

The second module, called Simulation Process, is based on ns-2 network simulator. We use more ns-2 instances to run more simulations simultaneously. Input to second module is TCL script from Simulation design. Every

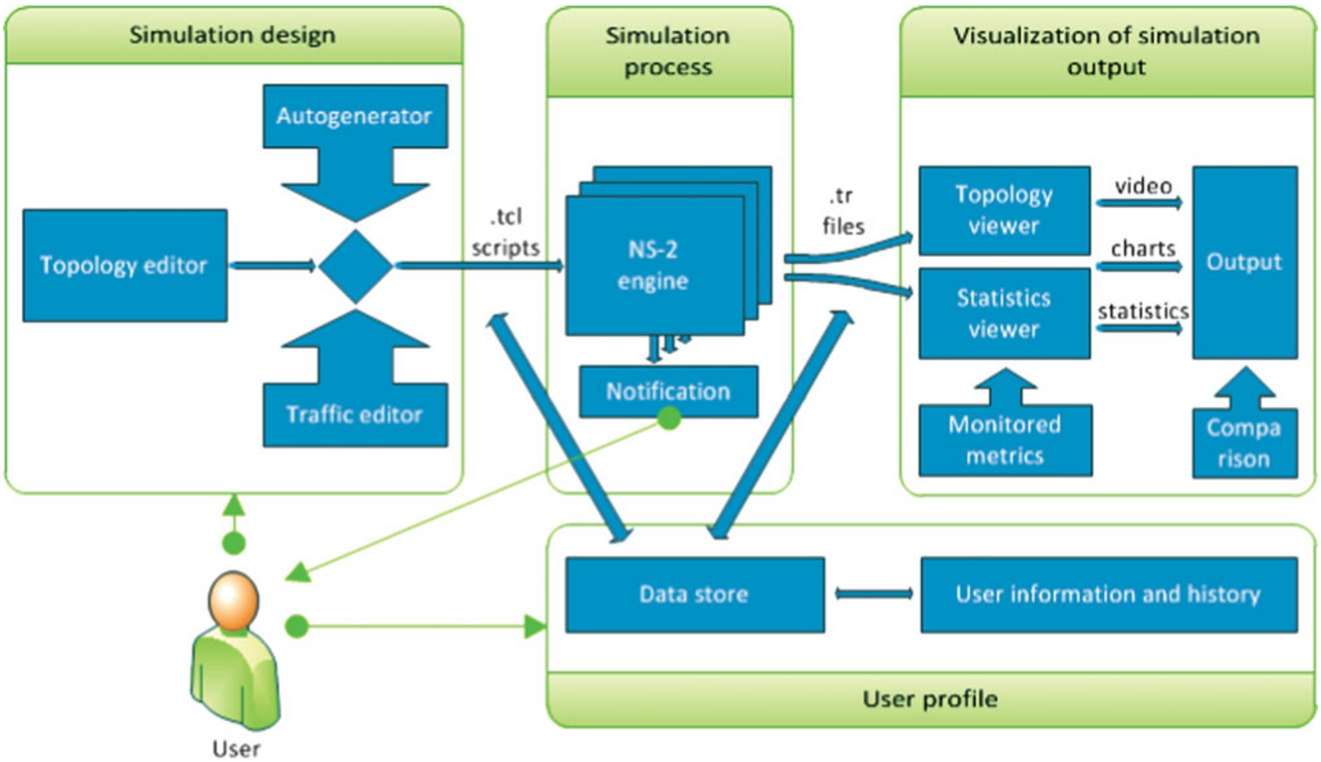


Fig. 1 NS2IT architecture

instance of ns-2 will create output trace file right after simulation described in input TCL script ends. In simulation process, we added feature Notification. Some of simulations can take really long time (couple hours), so NS2IT can notify user (via e-mail) when simulation is done.

A very important module, which makes our solution unique, is Visualization of Simulation output. Input for this module is trace file from ns-2 engine. This is the process where simulation output file is modified for visualization components. We prepare input for these components based on user's requests entered in Monitored metrics forms. There are two types of viewers. The first one is Topology viewer where user can watch his simulation and traffic. The second one is Statistics viewer. Based on monitored metrics, here are shown charts and statistics from simulation. Output of the third module is one summary of the whole simulation. Here, the user can see information which he requested in previous steps.

If there are more simulation summaries, user can pick them up and display them next to each other. This is useful in case, when user would like to compare behaviour of network under different circumstances (e.g. the same topology with different traffic, etc.).

The last primary module is User Profile. In this module there are no working components which cooperate to get the job done. Nevertheless, it is important for the whole solutions. This module is responsible for storing and handling all user's data. Every previous created TCL script and trace file can be recreated and modified to run a new simulation without the need to create everything from a scratch. All simulation summaries are stored in a history, so they can be picked up anytime to compare with a fresh new simulation summary on comparison screen.

As we can see in Fig. 1, there is a one-way flow relation among first three main modules. The output from one module is input for the next one. Only the fourth module, user profile, is connected by a two-way flow with the input and output of the second module Simulation Process. This means that any TCL and trace file is immediately stored in user profile's database and any of these files from database can be reused in a new simulation process. The high-level view of simulation process by means of NS2IT can be seen in the Fig. 2.

Simulation Preparation

As a standard ns-2 input is considered script written in TCL language. There are lot of things needed to be defined in this script such as network topology parameters, communication protocols and simulation timing [11]. Due to

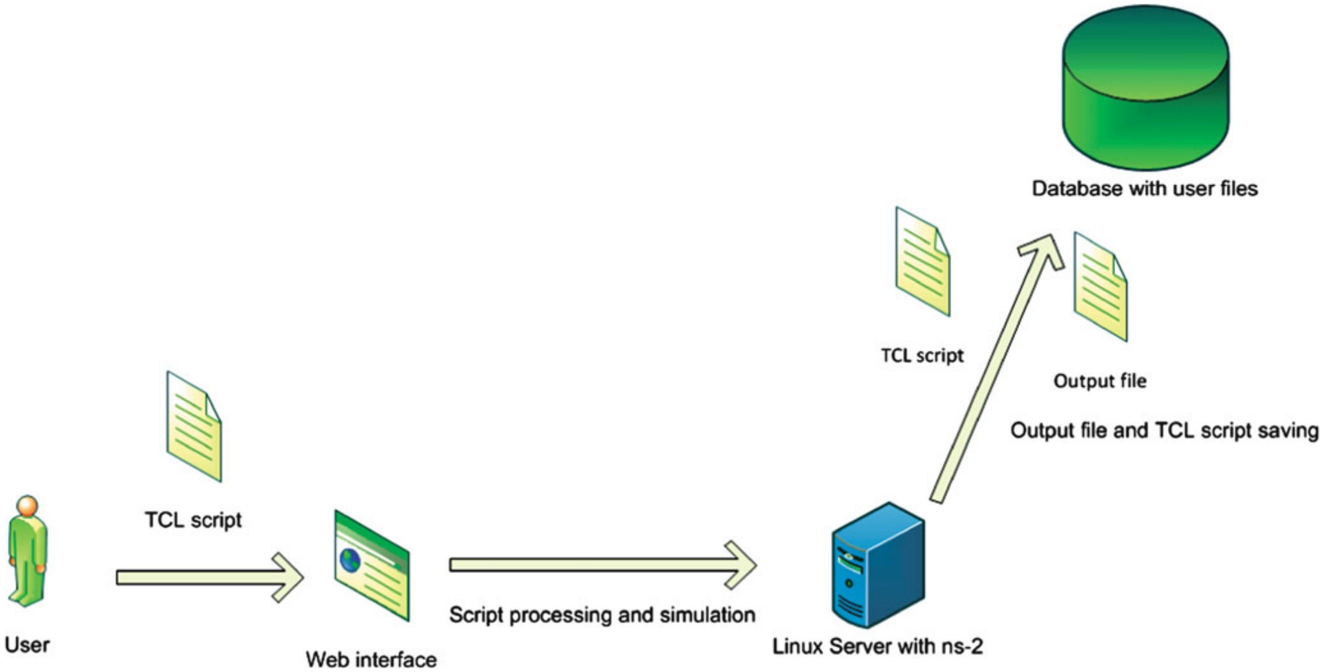


Fig. 2 NS2IT simulation process

complexity of these scripts and diversity of simulation possibilities, it is very difficult to achieve full automation of script preparation process. Therefore our solution provides only few possible simulation inputs.

The first possibility for user is to use already existing script, written by other user and stored in our database. Our solution includes also random generator for simple simulations. The advantage of this possibility is that there is no need for users to have any knowledge about ns-2-simulator and TCL scripting. They can just use NS2IT. Running simulation made by other user or generated by our system may help beginners to become familiar with our system functionality and capability. In addition, random generated simulation scenarios offers great possibility for network behaviour observation, considering randomness typical for Internet environment.

For advanced users there is a possibility to run their own home made simulations on our system. In this case topology and traffic editors may be helpful by partially automating TCL script creation. Nevertheless, good knowledge of ns-2 simulator and TCL scripting language is necessary. On the other hand, this method of input gives the user maximum control over simulation parameters. Before starting the simulation, user should choose network metrics he wants to evaluate and visualize after simulation to ensure their recording during the simulation.

After successful completion of the simulation, the user will be notified via e-mail and then will be able to work with the results through visualization screen interface.

Data Collection

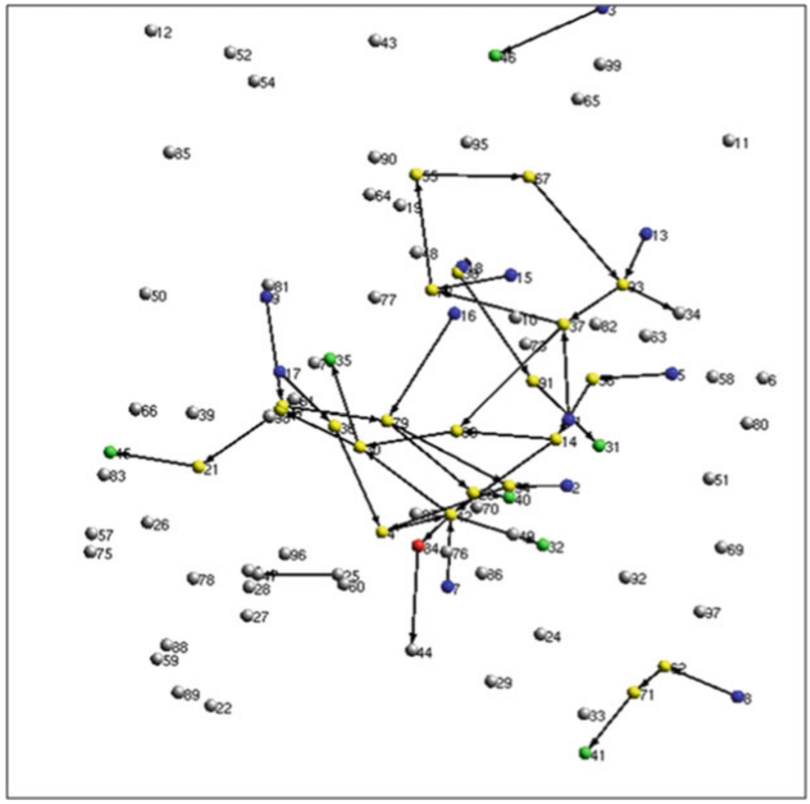
The main goal of proposed system is relevant data collection during the simulation and its transparent evaluation and comparison. However, not all required data necessary for network metrics computing are in ns-2 standard output, known as trace file by default. Therefore, there is a need to set required data collection in TCL script just before the simulation for its later processing.

We use numerous shell scripts for computing network metrics that the user intends to observe. In calculation process, data just recorded in trace file or other output files generated during simulation are used. Data from this output is sorted and filtered according to its relevance to particular metrics observed by the user. Calculated metrics can be further graphically and statistically evaluated and simulations can be compared with each other.

Visualization

The user interface is common XHTML 1.0 Transitional web site generated by server-side scripting language PHP. This enabled us to create dynamic web application and assured cross-platform availability. To provide better human-computer interaction, we used AJAX (Asynchronous

Fig. 3 Topology visualization



JavaScript and XML) programming features.[1] Many of our solution's features as simulation, data collection and preparation, measurements recalculation etc. have to be processed by various server scripts. Therefore we enhance user AJAX interactions by server-web interface. This module enables authorized web applications execute server shell scripts and access their outputs. All this is done with efficient and secure way.

The user has to be logged in, to interact with the web application and simulations. This ensures application about user identity. After successful authentication, user can create new simulation with various monitored measurements or access his previous simulations. Our interactive approach enables the user to watch the simulation progress and compare selected measurements.

Our main goal is to simplify reading of simulation's outputs. To achieve this goal with user-friendly approach, our solution provides following types of visualization:

- simple topology design visualization,
- graphs and charts of simulation output,
- comparison of several measurements.

Simple topology design visualization is generated by 3rd party solution iNSpect.[2] After simulation is done by ns-2-engine, iNSpect creates topology screenshot in time of simulation beginning. User is also able to record video sequences of chosen simulation parts. This feature is very useful for dynamic wireless networks. The output of this subsystem can be seen in the Fig. 3.

Graphs and charts are very useful for studying various network parameters as throughput, delay, delay variation (jitter), loss rate etc. After simulation is processed, user can choose network measurement or ask for measurement comparison. This request is send to server in asynchronous manner where needed data is chosen and calculated. Data is passed to plotter solution GnuPlot[3] and sent back to user as an image in form of chart as shown in Fig. 4.

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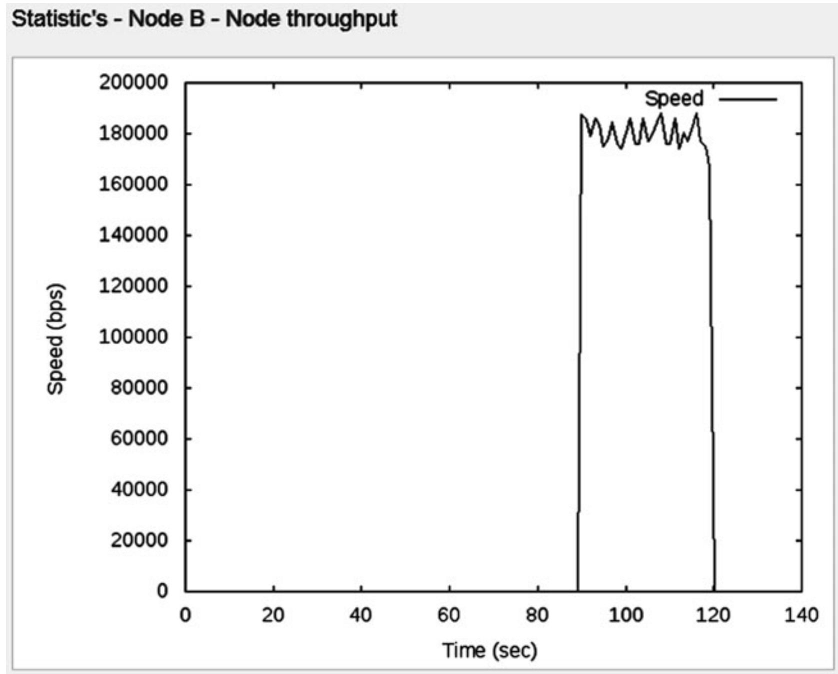

Fig. 4 Sample output chart generated from acquired data

Conclusions

In this paper we described our solution to simplification of the computer networks simulation. We introduced the reader to the background of the network simulation and the difficulties it brings, the input file along, with the complexity of the simulation output. We gave the reasons why the simplification of simulations is needed and how we are going to achieve it.

This paper also explained the possible advantages of our solution, in the contrary to the classic way of using the ns-2 computer network simulator. We proposed a highly portable and cross-platform accessible solution that could be used in many kinds of simulation with a wide range of use. Our goal is to make the network simulation using ns-2 simulator accessible and easy-to-use to a wide range of users, from total beginners to network professionals.

Acknowledgement This work was partially sponsored by VEGA under number 1/0722/12 "Security in distributed computer systems and mobile computer networks" and 1/0676/12 "Network architectures for multimedia service delivery with QoS guarantee". We thank also to all members of our research team, namely Hana Severínová, Roman Panenka, Martin Pirháč, Dávid Oros and Martin Svetlík.

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Survey on Decentralized Modular Robots and Control Platforms

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Abstract

Swarm robotics is a relatively new field that has utilized significant progress in the area of multi-agent robotic systems over the last two decades. At times, Swarm robotic systems adopt a decentralized approach in which the desired collective behaviors emerge from local decisions made by robots themselves according to their environment. On the other hand, traditional multi-robot systems basically use centralized communication control in coordinating each robot. The fact that typical swarm of robots consists of relatively simple and homogeneous robots allows the group to self-organize or dynamically reorganize the way individual robots are deployed. Therefore, the swarm approach is considered to be highly robust to the failure of individual robots. The decentralized approach not only addresses the fact that there is a shortage of available software frameworks for distributed control systems/robotics but also introduces system software for controlling multiple expandable and reconfigurable swarm agents. We investigate the behavior of many swarm systems that have been proposed in the literature. In this survey we provide a detailed summary of systems that have been classified under four main categories of the multi-robot system platforms namely; self-reconfigurable, modular, self-replicating, and swarm systems. We present a preliminary taxonomy for swarm robotics and classify existing studies into this taxonomy.

Keywords

Decentralized robots control • Decentralized swarm intelligence • Modular robotics • Swarm robot interactive software • Swarm system behavior

Introduction

Decentralized modular robotics is an emerging area that has attracted many researchers over the past few years. It has been proven that a single robot with multiple capabilities cannot necessarily accomplish an intended job whereas different robots, each one with its own configuration, are more flexible, robust and cost-effective. Moreover, the desired tasks may be too complex for one single robot, whereas they can be effectively done by multiple robots [4, 5]. Modular robotic systems have proven to be robust and flexible [2–4, 10, 11, 18]; such properties are likely to become increasingly important in real-world robotics applications. However, there is lack of software packages which provide control for various platforms of robots individually and allow concurrent control of heterogeneous robotic teams. Thus we will be interested in designing such control applications. Figure 1 shows the break-down of the system architecture:

Different research efforts have been carried out in the past decade that attempt to solve out coordination and decision making problems in swarm robotic systems. Such studies

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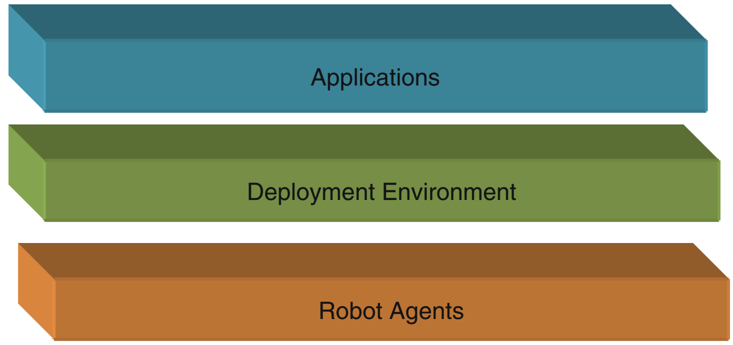
T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_23,

Fig. 1 System hierarchy



include simple models such as foraging [8, 11, 12]. The multi-agent robotics system consisting of a number of identical robots proposed in [13] for a decentralized robot is yet another approach to swarms. In Roderich and others [14] proposed the concept of self-assembling capabilities of the self-reconfigurable *swarm-bot* called S-bots. S-bots can either act independently or self-assemble into a swarm-bot by using their grippers. In Fukuda and Nakagawa [15] proposed the concept of the DRRS (dynamically reconfigurable robotic system) based on a cell structure for removable parts. The implementation was then called CEBOT, the first cellular robotic system. CEBOT is a heterogeneous system comprised of agents with different locomotion functions. One of the critical aspects of this type of systems is the communication between the members of the swarm [16], which is usually carried out using radio-links. In Dumbar and Esposito [17] studied the problem of maintaining communications among the robots performing tasks.

In conducting our survey we identified a criteria based on assumptions similar to the work presented in [48]. In other words, we are interested in systems that involve algorithms designed specifically to operate heterogeneous/homogenous robots performing various tasks. These assumptions can be summarized in the following assumptions:

- The systems examined are composed of undetermined number of embodied robots;
- Robots are identical or heterogeneous with different capabilities;
- Robots have decentralized control;
- More robots maybe added to the system at any time;
- Robots are multipurpose, not task specific;
- Coordination model should take place to operate the different robots.

We present a comprehensive study on the behavior of swarm systems dedicated to different tasks/applications with a new collective and mobile reconfigurable robotic system. The modules are fully autonomous mobile robots that, by establishing physical connections with each other, can organize into modular robots. We do not consider any particular hardware or infrastructure of each swarm agent, as our focus in our work is building control mechanisms that allow the system to operate several simple heterogeneous agents.

This survey is organized as follows: in section "Related Work" we provide a comprehensive survey of two primary swarm approaches namely biologically inspired and functionally built robots. A comparison between existing reconfigurable robots is presented in section "Reconfigurable Robots". Fourth section will provide some discussion about "Self-Replicating Robots". Section "Swarm Control Software Platform Systems" brings much analysis to the software operating application systems that have been introduced.

Related Work

Swarm behavior was first simulated on computers in 1986 with the simulation program Boids [1]. This program simulated simple agents (Boids) that are allowed to move according to a set of basic rules set by programmers. Those rules are simply algorithms usually called PSA or Particle Swarm Algorithm. The model was originally designed to mimic the flocking behavior of birds, but it can be applied also to schooling fish and other swarming entities.

Different studies of complexity have been carried out over these types of systems [7–25]. There have been many interpretations to the understanding and modeling of swarming behavior. Some researchers have classified these behaviors into two primary types namely biologically inspired and functionally built robots [30], while others have proposed two fundamentally different approaches that have been considered for analysis of swarm dynamics. These are spatial and non-spatial approaches [31]. In the first approach, "biologically inspired", designers try to create robots that internally simulate, or mimic, the social intelligence found in living creatures. While the second approach, "functionally designed", functionally designed robots generally have constrained operational and performance objectives.

Consequently, these "engineered" robots may only need to generate certain effects and experiences with the user, rather than having to withstand deep scrutiny for "life-like" capabilities [10].

Biology Inspired Robots

Multiple researchers have shown some interest in the foraging and other insect inspired coordination problem and have investigated these behaviors and summarized them into algorithms [19–22]. Others were interested in exploiting swarm robots in the tasks of localization [19], surveillance, reconnaissance [20], and hazard detection [21]. Pheromone-trail-based algorithms sometimes have the ability to dynamically improve their path [23] and can adapt to a changing terrain [27]. Ant-inspired foraging has been implemented in robots by various groups. One major difficulty can be exhibited in implementing the pheromone itself. Others resolved problems of how robots should interact in the swarm. There have been many approaches dedicated to this:

- *By means of physical markers*, where robots physically mark their paths in multiple ways, such as depositing of a chemical alcohol on the ground [23], drawing lines onto the floor using pen and paper [22], laying trails of heat [24], storing the pheromone values radio frequency identification tags RFID [25], or emitting ultraviolet light onto a phosphorescent paint [26].
- *Transmitting wireless signals when laying virtual landmarks in a localization space*. In the work of Vaughan et al., robots maintain an internal pheromone model with trails of waypoints as they move, and share it with other robots over a wireless network [27].
- *Virtual pheromones* that consist of symbolic messages tied to the robots themselves rather than to fixed locations in the environment. In their experiment [20], the virtual pheromone is encoded as a single modulated message consisting of a type field, a hop-count field, and a data field. Messages are exchanged between robots through infrared transmitters and receivers. It is assumed that the robots that receive the pheromone can measure the intensity of the IR reception to estimate their distance from the transmitter.
- *Foraging allocation ratio among robots*. In Liu et al. [28], presented a simple adaptation mechanism to automatically adjust the ratio of foragers to resting robots (division of labor) in a swarm of foraging robots and hence maximize the net energy income to the swarm. Three adaptation rules are introduced based on local sensing and communications. Individual robots use internal cues (successful food retrieval), environmental cues (collisions with teammates while searching for food) and social cues (team-mate success in food retrieval) to dynamically vary the time spent foraging or resting.
- *Dynamic programmed deployable beacons*. The method in [29] provides local rules of motion for swarm members that adhere to a global principle for both searching and converging on a stationary target in an unknown and complex environment via the use of immobile relay markers.

The survey does not span the entire field of intelligent swarm behavior robotics. Instead, it focuses on systems for which new algorithms for communication between robots have been demonstrated. Such algorithms can be found in the work of the following researchers.

Algorithm for Self-Organized Aggregation of Swarm Robotics Using Timer

As a solution to self-organization among swarm agents, Yan et al. [4] have proposed an aggregation algorithm based on some constraints where neither central control nor information about locations of the agents are pre-given. The author's control strategy contains two states, Search and Wait for each individual robot as given in the model of probabilistic finite state automata (PFSA). Their algorithm assigns unique IDs to each robot. Knowing the total number of robots, randomly placed robots walk in the arena looking for other robots. Based on IR sensing and wireless connection capabilities installed on each robot, each can identify the others robot's ID. The one with the larger ID defines the aggregate and timers such that robots in the same aggregate must have the same timers. When the timer is timeout, the robot tries to leave from its current aggregate. In the experiment, all the robots are identical. The robot is mobile with limited ability of interaction including IR sensing for detecting objects and wireless communication for communicating with other robots.

Two Foraging Algorithms Using only Local Communications

Hoff et al. [7], have proposed two algorithms for searching the environment for an object of interest and then returning the food to the base, having in mind that all robots do not have any prior information about the location of the food. Their algorithms are inspired by the foraging behavior of ants where they mark paths leading from the nest to food by depositing a chemical pheromone on the ground. Ants use the distribution of pheromone to decide where to move.

In their first algorithm, two simple flouting-point values are used such that some robots will decide to stop their normal search and become 'pheromone robots' at any given point. Those robots will act like locations of virtual pheromones. Other robots can read the pheromone level by receiving a transmission from the pheromone robot, and they can lay virtual pheromone by transmitting to the pheromone robot. So, if there were a network of pheromone robots, the walker robots could use the distribution of virtual pheromone they can sense to decide how to move. If integer values are used instead of flouting-point value at each virtual pheromone such that the nearest robot to the nest stores a 1 and the other one close enough to hear the first robot stores and transmits a 2, then a walker robot can use these values to find a path to the nest by always moving to the lowest cardinality it can hear. This is the core idea of their second algorithm.

Functionally Inspired Robots

Another line of swarm-based research can be found where robot agents are built to achieve specific tasks such as path finding using algorithms that are not necessarily based on imitating biological swarm organisms. In their previous work, Wang et al. [32] implemented what they call it robotic termite agent, which is able to simulate the wood-chip collecting behavior of the termite. Authors have developed software and hardware solution based on the simulation of collective building of a 2D termites' colony. The termites (swarm of robot agents) gather wood chips into piles following a set of predefined rules. Boe-Bot Robots are used. The Boe-Bot was built on an aluminum chassis that provides a sturdy platform for the servomotors and printed circuit board and comes with a pair of whiskers and gripper. Their tasks include moving on smooth surfaces, detecting new objects, picking up an encountered new object and dropping the woodchip it carries when encountering another object. A robot agent will keep on spinning left (360°) until it detects an object. The robot will then carry the object and will keep holding it and moving around until it detects another object (woodchip) then it releases it. After releasing the object, the robot moves backward, turns an angle of 45°, and the same procedure is repeated.

Obtaining decentralized control that provides interesting collective behaviors is a central problem [41–49, 59]. Several algorithms have been developed to run on swarms of robots. The complexity varies between these algorithms. Some provided basic functionality, such as dispersion, while others exhibited complex interactions between the team of robots such as bidding on tasks according to some rules. Table 1 summarizes most recent swarm robot systems with their corresponding algorithms. These are systems introduced in literature that only involve multiple agent teams with decentralized control.

Reconfigurable Robots

Reconfigurable robots automatically rearrange and change their shape accordingly to adapt themselves to different environments of application. Reconfigurable robots exhibit some features make it possible for the robots to adapt for different tasks. For example shape shifting robots could form a worm-like shape to move through narrow spaces, reassemble into spider-like legged robot to cross uneven terrain. Another important feature of modular robots is their potential for self repair. As the modules making a unit up are usually identical, it is possible to eliminate the damaged module and substitute it using another one, if available. Modular robots are usually composed of multiple building blocks of a relatively small repertoire, with uniform docking interfaces that allow transfer of mechanical forces and moments, electrical power, and communication throughout the robot.

According to Yim et al. [50], Modular selfreconfigurable robotic systems can be generally classified into three architectural groups based on the geometric arrangement of their units. First, lattice Architectures where robot units are arranged and connected in some regular, three-dimensional pattern, such as a simple cubic or hexagonal grid. Second, chain/tree Architectures where units are connected together in a string or tree topology, and third, mobile Architectures where units use the environment to maneuver around and can either hook up to form complex chains or lattices or form a number of smaller robots that execute coordinated movements. A respectable number of self-reconfigurable robot systems have been proposed in the last decade. Table 2 shows comparisons between the most recent ones.

Self-Replicating Robots

The concept of self-replicating machines was introduced by von Neumann [33] more than six decades ago and was implemented through basic attempts to create systems that mechanically replicate themselves under external agitation [33–35]. However, designing fully autonomous replicating systems did not come true until the early 2000's. An attempt to design semi-autonomous self-replicating robots that demonstrated the LEGO Mindstorm kits as a prototype capable of replication under human supervision was introduced in [36]. An autonomous self-replicating robot consisting of four low-complexity modules was presented in [39]. Authors' proposed a system composed of a parent robot, four unassembled modules, and an environment where the self-replication takes place. Authors defined two operations namely expansion and separation where the parent robot grows itself by attaching the resource modules onto itself until it doubles its physical size, and then splits in the middle thereby returning the parent to its original state and producing one more robot. The parent robot is made of four cube-like modules connected to each other with electromagnets (EMs) installed in female and male couplers.

Table 1 Multi-robot coordination approaches

Approach			Remarks
Approach 1: Knowledge-based coordination			
Symprion/ replicator projects	What determines the behavior of either single or group of agents is HDRC (hormone driven robot controller) controller that contains a configuration for the robot itself, and a software controller called Genome. The Genome contains a set of rules that control each agent's behavior and generates different actions according to the different environment conditions. Agents keep learning about their environment using internal, external and virtual sensors. Agents also are supported with on-board computational power using approaches like generic programming (GP) and Genetic Algorithms (GA)	Kernbach et al. [59]	The most primary advantage of this approach is the massive number of units used in performing an ultimate goal that is to explore. Moreover, Modules are able to reassemble different shapes that could get the whole structure moving to desired locations
iRobot	Authors suggest spreading pheromones in an ad-hoc way over the wireless network constituted by the robots. The primary communication component is an infrared interrobot communication. Swarm software is written as behaviors that run concurrently. Each behavior returns a variable that contains actuator commands. Their goal is to spread robots throughout an enclosed space quickly and uniformly, that was identified by direct dispersion performed by two algorithms. The first one works by moving each robot away from the vector sum of particular positions from their closest neighbors. In the second algorithm robots move towards areas they have yet to explore. Once the robots know their positions the frontier robots issue a message. The trees created by these messages guide the Swarm towards the frontier robots	McLurkin and Smith [43]	Their solution mainly focused on path planning and routing protocols of messages transmitted between agents at their different positions. However, problems may occur due to the cost of individual robots and to the number of robots required to provide a good and dense enough coverage of the environment. Also, the approach suffers from the fact that when the ad-hoc network of robots gets partitioned, pheromone trails automatically break down
Approach 2: Auction-based coordination			
Layered architectures coordination	Authors propose auctions to secure teammate participation in subtasks that require tight coordination between multiple robots, but implement the tight coordination using an inexpensive reactive approach. Each robot consists of a planning layer that decides how to achieve high-level goals, an executive layer that synchronizes agents, sequences tasks and monitors task execution, and a behavioral layer that interfaces to the robot's sensors and effectors. Robots execute plans by dynamically constructing task trees	Simmons et al. [44]	The three robots used in this experiment are coordinated by a manipulation manager which means this is a centralized system
ASyMTRe-D and market-based task allocation	Authors approach is based on schemas such as perceptual and motor schemas. Inputs/outputs of each schema create what it is called semantic information that is used to generate coalitions. Tasks are assigned to the robot with the highest bid. Bids are calculated according to the costs of performing different tasks. A set of tasks are allocated to coalitions. Coalition values are calculated based on the task requirement and robot capabilities. Execution of tasks is monitored and the process of allocation repeats itself until each individual task is completed. During run-time their novel protocol ASyMTRe-D takes place. This protocol manipulates calculated coalition values to assist in completing tasks	Tang and Parker [60]	The advantage of this approach is that it enables robots to adopt new task solutions using different combinations of sensors and effectors for different coalition compositions. However, that solution is mainly related to computational performance where tasks are static Authors did not mention the dynamical tasks and ways of task reassignment, additionally, they did not discuss fault tolerance, flexibility, robustness, and how the system reacts to any robot failure
RoboCup 2002 (sony legged league)	Authors used wireless communication between robots in a 4-player soccer team. Each robot broadcasts a message to its teammates. This message contains the current position of the robot	Vail and Veloso [45]	Communications between robots is critical for successful coordination between robots. Local information about the field will not be enough

(continued)

Table 1 (continued)

Approach			Remarks
	and some other information about the ball in that position. All of the robots use the same set of functions to calculate real valued bids for each task. Once each robot calculates the bids for itself and each of its teammates, it compares them. If it has the highest bid for the role being assigned, it assumes that role. If it was not the winner, it assumes that the winning robot will take up the role and performs calculations for the next role in the list		This approach does not coordinate a large scale of robots
Another application of soccer robots.	Authors used dynamic role assignment as in Robocup basing on information gathered from best behavior. Two intermediate levels have been provided to allow robot individuals to communicate. The lower level implements stigmergy; whereas, the higher one deals with the dynamic role exchange. Authors used schema-based methodology. They discussed all perceptual schemas with the required sensing, also feeding the C-implemented motor schemas which demand immediate sensor data Robots are equipped with unidirectional cameras	Pagello et al. [46]	
M + scheme for multi robot allocation and corporation	Each robot considers all currently available tasks at each iteration. For each task, each robot uses a planner to compute its utility and announces the resulting value to the other robots. Robots negotiate which one will be in charge of performing the task. For these tasks, robots create their own individual plans and estimate their costs for executing these tasks. The robots then compare their costs to offers announced by other robots. The robot selects to perform the task of lowest cost that it can perform that is better than the cost announced by any other robot. Upon receipt of the other robots' utilities, each robot executes a greedy task-selection algorithm	Botelho and Alami [47]	Relying on Negotiation Protocols, may complicate the design of the coordinating system Furthermore, such negotiation scenario can drastically increase communication requirements/ overhead
MURDOCH, a general task allocation system	The coordination system works using auction protocol that allocates tasks via a sequence of first-price one round auctions. Every auction is issued by agents in five steps: task announcement, metric evaluation, bid submission, close of auction, progress monitoring/contract renewal. For each task auction, each available robot broadcasts its bid. Because of the asymmetric nature of MURDOCH's auctions, the running time varies between the bidders and the auctioneer. Authors two main testing domains were a long-term scenario consisting of many loosely coupled single-robot tasks, and a cooperative box-pushing task requiring tight coordination among the robots	Brian P. Gerkey and Mataric [48]	M + and MURDOCH systems assume that each robot has a single task. Each task may be performed by a single robot. This assumption is proving to be oversimplified as many task domains require simultaneous work from multiple robots
Market-economy Approach	Authors defined three strategies for exploring unvisited regions. In the first strategy namely random goal point selection the goal points are chosen at random and discarded if the area surrounding the goal point has already been visited. In the second one, the goal point is centered in the closest unexplored spot as a candidate exploration point. In the last strategy, the region is divided into its four children if the fraction of unknown space within the region is above a fixed threshold Robots are initially placed into known positions. While running, each robot will try to sell each of its tasks to all robots with which it is currently able to communicate via an auction. If two robots lie in the same region, the robot with the highest bid wins that region's task	Zlot et al. [49]	Authors considered regions of potential target locations for each robot and distributed tasks using bid auctions According to some experiments performed by [62] this approach could be useful if the number of robots is small compared to the number of frontier cells. However, in the case of multiple robots this approach can be disadvantageous. That is a robot discovers a new frontier during exploration and this robot will often be the best suited to go on it. This can lead to an unbalanced assignment of tasks and the overall exploration time is increased

Table 2 Comparisons between existing modular reconfigurable robot systems

Robot	Author	Accomplishment	Software	Units	Communication	Sensors
SuperBot (2006)	Shen et al. [51]	Decentralized control. Reliable Mechanical design	Real-time java-based operating system	3D Modules	Electrical	Joint position and orientation
Molecubes (2005)	Zykov et al. [52]	Physical reproductive cube modules	2-D simulation	Cubes with 120 swiveling	none	none
YaMor (2006)	Moeckel et al. [53]	Each module comprises an FPGA for more computational power	Java-based GUI connected to robots via wireless connections	3D Chain of modules	Electrical	Joint position and orientation
Swarm-bot (2006)	Groß et al. [14]	Integration of more than 50 sensors in each module	Neural Networks	S-bots with grippers	Electrical	Joint position and orientation
Catom (2005)	Goldstein et al. [54]	Largest actuated modules (many electromagnets on modules)	NA	3D Massive volume of agents ($m^{3)}$	Electrical	Joint position and Oirentation
M-TRAN (2002)	Murata et al. [55]	Fewer DOF modules that utilize two classes of systems	OpenGL Library, M-TRAN simulator	3D Double-Cubes	Electrical	Joint position and orientation
ATRON (2004)	Østergaard et al. [57]	Very reliable mechanical design	On-board system	Lattice type units	Optical	Joint position, orientation and proximity
PolyBot (2002)	Yim et al. [58]	Strongest actuation	NA	lattice	Optical and electrical	Joint position, docking aid and orientation
Replicator/ Symbri on (2008)	7th framework program project, European Communities [59]	Multiple processors for different tasks	On-board system	Lattice/chain	Optical and electrical	Joint position, docking aid and orientation

In [40], similar work has been also done using unassembled components placed at certain locations on a track. Authors presented a robot that can assemble exact functional self-replicas from seven more basic parts/subsystems. The robot follows lines on the floor using light sensors and a simple control circuit without any onboard memory.

Swarm Control Software Platform Systems

Trifa et al. [6] have proposed a methodology to support standardized interfaces and communication protocols that connects robots produced by different manufacturers. To achieve this goal, authors have used the so-called service oriented architecture (SOA) in which different software components exchange data over HTTP and then create Web Services (WS). The authors proposed a system that consists of four parts namely, the physical layer which contains the actual e-puck robots, the gateway layer which acts like a connection between the physical devices and the system, the logic layer containing a server that runs on J2EE, and the interface layer which provides services to the end users. In their system, any physical device or program capable of running HTTP such as PDAs, Tablet PC, and mobile phones can interact with the interface regardless of the operating system on the device (No further explanation about control modules or how the interface looks like was given in the article). The e-puck robot—the standard one—has eight infrared proximity and light sensors, a triangular microphone array, a speaker, a three-axis accelerometer, and a Bluetooth interface for programming. The e-puck platform can be upgraded with custom pluggable modules such as the short-range radio communication turret which provides a subset of the 802.15.4 and ZigBee protocols and is fully interoperable with the MicaZ nodes used in the physical gateway layer. However, using SOA has some performance limitations as it requires a sophisticated messaging infrastructure that would restrict the capabilities of software running on robots.

Kulis et al. [56] have proposed a software framework for controlling multiple robot agents by creating what they have named the Distributed Control Framework (DCF). DCF is an agent-based software architecture that is entirely written in Java and can be deployed on any computing architecture that supports the Java Virtual Machine. DCF is specifically designed to control interacting heterogeneous agents. DCF

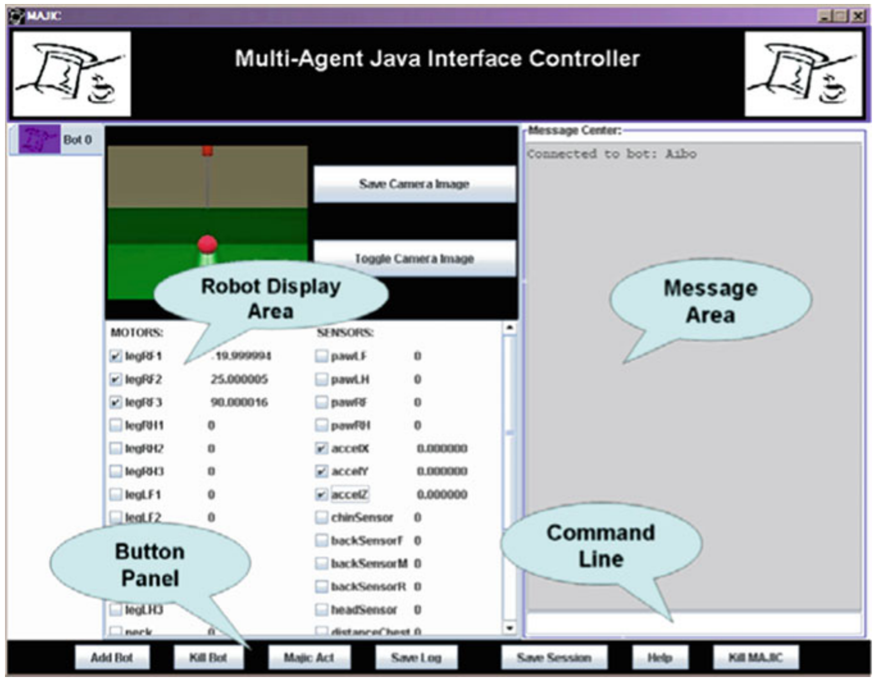


Fig. 2 The MAJIC control platform (©2008 IEEE) (©[2008] IEEE, Permission granted by Dr. Craig Martell)

uses a high-level platform-independent programming language for hybrid control called MDLE. The DCF architecture consists of two distinct agents: a Robot Agent and a Remote Control Agent (RCA). Robot Agents process data from onboard hardware and from other agents, and react to perceived stimuli by selecting an appropriate behavior which is a sequence of control laws with embedded state transition logic according to a mission plan. Using the RCA, the end user can select tasks for either a robot agent or a group of agents using simple drag and drop operators. When agents are in place, a popup menu appears prompting the user to select a task. Relevant tasks for a team mission are defined in an XML configuration file which is loaded by the RCA at startup. The XML file also specifies which tasks can be performed by each agent. Authors also added a simulating feature to their RCA agent which provides a flexible numerical solving integrating system that solves differential equations for simulating a robot's kinematics/dynamics. Another feature of this system, it provides automatic updating of sensors and actuators to be distributed across multiple computing resources. The DCF currently provides drivers for a variety of robots (e.g., iRobot Creates, Pioneers, Amigobots, FireAnt, LAGR), and a wide ranges of sensors (e.g., digital encoders, sonars, stereo cameras, GPS receivers, inertial navigation systems, LIDARs, and cameras) [61]. Multiple efforts have been conducted as part of enhancing the DCF system. An enhanced JAUS and TENA compliant version of DCF is being developed and tested [61].

Ball et al. [8], have proposed application software built in JAVA to operate heterogeneous multi-agent robots for the sake of educational purposes namely MAJIC. The system provides basic components for user interaction that enables the user to add/remove robots change the robotic swarm configuration, load java scripts into robots and so on as shown in Fig. 2. The system establishes communications with built-in robot servers via a wireless connection that uses client/server relationship. Authors described their architecture as components, consisting of one higher level component that is the GUI manager, and two application logic components that consist of a Logic System to parse input into valid commands, and a Robot Server, which receives commands from the Logic System and communicates those commands to the appropriate robot. Local components communicate using direct procedure calls.

In order to operate robots, the operator needs to write java embedded programs that use either the MAJIC library or Java libraries. Once a robot is connected to MAJIC, the user can immediately communicate with it from the Command Line. However, repeating this process for a team of heterogeneous robots can be impractical. The MAJIC system does not allow the user to specify the types of sensors a robot is equipped with or the type of motion model a robot's move command will utilize that could allow the user to develop more intricate behaviors with greater precision.

In [37], Patricio Nebo et al., were more interested in developing cooperative tasks among teams of robots. Their proposed architecture allowed teams of robots to accomplish tasks determined by end users. A Java-based multi-agent development system was chosen to develop their proposed platform. The authors have used *Acromovi* architecture which is a distributed architecture that works as a middleware of another global architecture for programming robots. It has been implemented by means of the MadKit (Multi-Agent Development Kit) multi-agent systems framework. The graphical interface is built around pure Java Swing components, thus resulting in a cross platform application, capable of running in any operating system running the Java virtual machine.

According to Zhang et al. [38], the platform they proposed is comprised of a central distributed architecture as it runs in a network environment. Their system is composed of four parts namely User Interface, Controlling Center, Robot Agent and Operating Ambient making up the platform top-down. The user Interface can be deployed on a terminal anywhere as long as it can connect to the server where the Control Center is deployed. The Control Center provides APIs for users. The User Interfaces basically communicate with the Control Center via network, using TCP/UDP protocol. Authors' platform was mainly developed in Java.

Conclusion

Robotic swarm collective intelligence uses small non-intelligent or slightly-intelligent robots that collectively perform complex tasks. The concept is borrowed from bees and ants, which have very limited intelligence and behaviors but can survive, reproduce, carry out tasks, attack and protect each other if they work in groups or with the entire colony. The overall high intelligence of the group is actually created by the simple acts and moderate local intelligence of each individual. Swarm robotics aim to develop very simple and inexpensive robots that individually perform very simple behaviors such as catching images on a camera, moving things around, communicating with nearby peers and doing very simple laser scanning. When put together, these robots can perform very significant and complex tasks in parallel much cheaper, faster and more efficiently than one or more very complex and expensive robotic agents. Another example is the task of painting a room, instead of deploying one smart and expensive robot, having 50 or a 100 smaller and very cheap ones with limited aptitude would have the entire room painted in a fraction of the time as of one robot and at a much smaller price tag. Such smaller agents would each have location sensors, simple communication modules, and vision capability to be able to move away from each and start painting their little part of the wall in parallel.

Related work on nine swarm operating platforms were presented, compared and discussed. We found that swarm systems lack supporting some performance data on how well the whole swarm system that is composed of either homo or heterogeneous agents will behave in performing the different tasks when varying the number of robots. Moreover, there was insufficient discussion about a graphical user interface that provides the user a set of choices to configure the swarm system and then provides another set of options to test the system against some performance criteria. Based on this survey, design considerations leading to a novel design of a swarm system platform will be analyzed thoroughly in our next step.

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Utilising Fuzzy Rough Set Based on Mutual Information Decreasing Method for Feature Reduction in an Image Retrieval System

Maryam Shahabi Lotfabadi, Mohd Fairuz Shiratuddin, and Kok Wai Wong

Abstract

Content-Based Image Retrieval (CBIR) system has become a focus of research in the area of image processing and machine vision. General CBIR system automatically index and retrieve images with visual features such as colour, texture and shape. However, current research found that there is a significant gap between visual features and semantic features used by humans to describe images. In order to bridge the semantic gap, some researchers have proposed methods for managing and decreasing image features, and extract useful features from a feature vector. This paper presents an image retrieval system utilising fuzzy rough set based on mutual information decreasing method and the Support Vector Machine (SVM) classifier. The system has training and testing phases. In order to reduce the semantic gap, the propose retrieval system used relevance feedback to improve the retrieval performance. This paper also compared the proposed method with other traditional retrieval systems that use PCA, kernel PCA, Isomap and MVU for their feature reduction method. Experiments are carried out using a standard Corel dataset to test the accuracy and robustness of the proposed system. The experiment results show the propose method can retrieve images more efficiently than the traditional methods. The use of fuzzy rough set based on mutual information decreasing method, SVM and relevance feedback ensures that the propose image retrieval system produces results which are highly relevant to the content of an image query.

Keywords

CBIR system • Fuzzy rough set • Mutual information • Relevance feedback

Introduction

In recent years, Content-Based Image Retrieval (CBIR) system has become a focus of research in the area of image processing and machine vision. General CBIR system automatically index and retrieve images with visual features such as colour, texture and shape [1]. However, current research found that there is a significant gap between visual features and semantic features used by humans to describe images. In order to bridge the semantic gap, some researchers have proposed methods for managing and decreasing image features, and extract useful features from a feature vector [2].

Each image in an image retrieval system is represented by its features such as colour features, texture features and shape features. These three groups of features are stored in the feature vector. Therefore each image managed by the CBIR system is associated with one or more feature vectors [3]. As a result, the storage space required for feature vectors is proportional to the amount of images in the database. In addition, when comparing these feature vectors, the CBIR system understand which images in the database are similar to another [1]. Nonetheless, researchers are still

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_24,

facing problems when working with huge image database since so much time is spent to compare huge feature vectors that require large amount of memory to run the CBIR system. Due to this problem, feature reduction methods are employed in order to alleviate the storage and time requirements of large feature vectors. There are many feature reduction methods, including the linear projection methods such as the Principal Component Analysis (PCA) and the Linear Discriminate Analysis (LDA), and the metric embedding techniques (both linear and non-linear) [4]. However, these methods could not improve the image retrieval performance and efficiently reduce the semantic gap. Therefore, an efficient feature decreasing method that can deal with image features is required.

Even though research on CBIR systems has been carried out for quite some time now, some of the issues such as handling the semantic gap, processing large amount of image features and, dealing with incomplete and vagueness in image feature vector are still unresolved. From literature, researchers have proposed various methods to overcome these problems [1, 5].

In this research, the authors propose a pre-processing stage to overcome these problems and improve the CBIR system. Using fuzzy rough set based on mutual information method in the pre-processing stage of the system, can select important features from a massive image feature vectors, and omitting features which are not important. These redundant features could influence further analysis in the wrong direction. Consequently, from these significant features, semantic rules are then extracted that can classify the images more accurately and show more relevance images to the user hence improving the retrieval performance [4]. In addition, in this system relevance feedback is used to bridge the semantic gap. Relevance feedback is an iterative supervised learning process which consists of two steps: (1) the user labels a set of "relevant" and "irrelevant" images as training samples and (2) the parameters of the system are updated and a set of better retrieval results is returned [3]. The learning process terminates when the user retrieves a set of satisfactory results. In order to improve the performance of CBIR systems, the relevance feedback is a powerful method.

Section "Related Work" of this paper presents a brief literature review. Then, in section "Stages of the Proposed Image Retrieval System", the authors briefly describe the stages of the work. The experimental results on the COREL image database are presented in section "Experiment Results", and finally in section "Conclusion", the authors conclude the study.

Related Work

In this section, a number of related papers are discussed. Current research related to image retrieval can be divided into two strands; one focusing on text query e.g. Google's image retrieval system, and the other on image query e.g. the IBM QBIC system. Since this research is more concerned with the Content Based Image Retrieval (CBIR) system, the second strand is therefore more relevant.

In [6], the research scope focuses on the development of a CBIR system for non-texture image databases. Using this approach, the authors combined a well-known clustering algorithm k-means with B^+-tree data structure. Although they can reduce the size of the search space considerably, their work has some limitations. They have not used image segmentation. Finding the segments of the images and developing a similarity criteria based on the similarity of objects in the images would enhance the accuracy of their system for images which contain multiple objects. In this similarity criterion, they can give the background a smaller weight and a higher weight to objects in the centre. Such a similarity measure would reflect better of the human perception.

Research conducted by [1] introduces the Fast Compression Distance (FCD); a similarity measure based on compression with dictionaries directly extracted from the data. The FCD uses offline extraction of a dictionary for each object which has previously been encoded into a string. In the string encoding step, some textural information is embedded within each pixel value to preserve as much information as possible. Subsequently, similarities between two objects are computed through an effective binary search on the intersection set between the relative dictionaries. The FCD has a reduced computational complexity with respect to the most popular compression-based similarity measure i.e. the Normalized Compression Distance (NCD). The NCD processes iteratively the full data in order to discover similarities between the objects. One disadvantage of the FCD is that it is less suitable for the detection of objects within a scene.

In [7], a simple and yet efficient CBIR based on orthogonal polynomials model is presented. This model is built with a set of carefully selected orthogonal polynomials and is used to extract the low level texture features present in the image under analysis. The orthogonal polynomials model coefficients are reordered into a multi resolution sub band like structure. Simple statistical and perceptual properties are derived from the sub band coefficients to represent the texture features and these features form a feature vector. Authors concluded that the field is expanding rapidly, but many major research challenges remain, including the difficulty of expressing semantic information in terms of primitive image features, and the need to significantly improve the user interfaces.

In [8], they proposed a method to automatically annotate image through the rules generated by the support vector machines and decision trees. In order to obtain the rules, they collect a set of training regions by image segmentation, feature extraction and discretisation. They first employ a support vector machine as a pre-processing technique to refine the input training data and then use it to improve the rules generated by decision tree learning. This method requires some parameters to be specified in order to find the appropriate clusters. In addition Searching images with a similarity threshold range gave researchers the opportunity to overcome the limitations of clustering in small sized clusters.

In summary and based on the abovementioned related works, the semantic gap continues to be a big challenge for image descriptors, especially in the context of information retrieval (in opposition to image classification with large learning sets). Users' assignment of answer relevance based on a single image is subtle, because obviously, a single image may represent many different concepts. The necessity to represent a main object capturing the concept of interest over variable complex backgrounds is also a challenge.

Although there are some improvement methods of traditional CBIR as shown in [1] or as suggested new methods in [2] and [9], most of the methods have problem with huge image features.

Stages of the Proposed Image Retrieval System

In this paper, Fig. 1 shows the stages of the proposed image retrieval system used in the experimental study. In Fig. 1, the system has training and testing phases. Firstly, in the training phase, the shape, colour and texture features of the image database are extracted. The features are then decreased by using fuzzy rough set based on mutual information method. Semantic rules are then generated with these features. After that, the SVM classifier is built using these semantic rules.

Still referring to Fig. 1, in the testing phase, user feed the query image to the system. The system extracted the queried image features and gave these features to the SVM classifier which is built in the training phase. This classifier represents the relevant images with query image to the user. After that, the user can give his/her feedback to the system. If the user is not satisfied with the results, the user will give feedback to the system and the system will apply it to the classifier before showing new retrieval results. This relevance

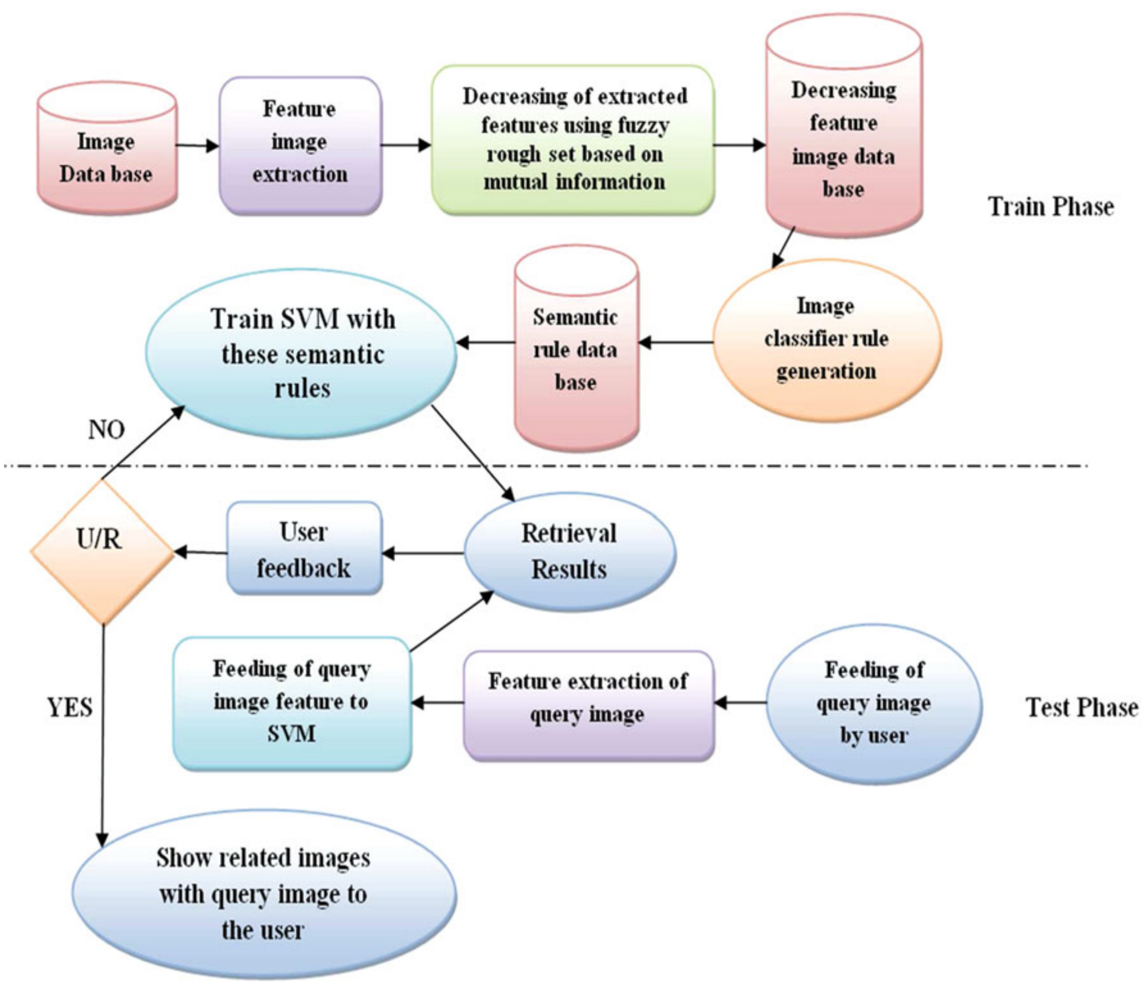

Fig. 1 Stages of proposed image retrieval system

feedback between the user and the system will happen continuously until the user satisfies with the results.

The fuzzy rough set based on mutual information decreasing method is described here. This decreasing method is based on the work from [10]. The fuzzy rough set based on mutual information method starts with an empty set and it seeks the relative reduction from bottom up. The process of this algorithm is: selecting the most significant attribute for adding to the relative potential reduces one by one, according to the significance of condition attribute, until the ending condition is satisfied. The algorithm of this decreasing method is as follows:

Step-1. Compute the mutual information I(C; D) between condition attribute set C and decision attribute set D in the fuzzy decision table.

$$I(C;D) = H(D) - H\left(D\middle|C\right)$$

$H(D)$ is information entropy and $H(D|C)$ is conditional entropy.

Step-2. Let $R = 0$, do{

1. For every attribute $A^j \in C - R$, compute the significance of fuzzy condition attribute A^j i.e. $SGF(A^j, R, D)$; (R is a subset of fuzzy condition attributes. $SGF(A^j, R, D)$ = I(R ∪ {A^j}; D) − I(R; D))
2. Select the attribute which brings the maximum of significance $SGF(A^j, R, D)$, then record it as A^j (if it exists as multi attributes achieving the maximum at the same time, choose one that has the least number of equivalence classes as A^j); then $R \Leftarrow R \cup \{A^j\}$;

} Until $I(C; D) = I(R; D)$;

Step-3. Condition attribute set R is the relative reduction required. It is worth highlighting the following aspects of the proposed method.

- Image query removes the difficulty of describing the feature of an image into words when similar images are searched.
- The fuzzy rough set based mutual information method as a pre processing stage makes the proposed approach more robust than conventional approaches.
- This proposed system can effectively and efficiently handle large image databases, and can be smoothly embedded into different image retrieval systems.
- This retrieval system refines decision rules of image retrieval by fuzzy rough set based mutual information.
- Rough sets provide reasonable structures for the overlap boundary, given domain knowledge.
- The proposed method can work efficiently in vague and uncertain area.

The SVM is used as a classifier in the proposed method. In an image annotation and retrieval, SVM is a widely used machine learning method. SVM can generate a hyper plane to separate two data sets of features and provide good generalisation. SVM is used as the learning tool to handle image retrieval problems [8]. SVM is known to perform well with noisier data compared with other machine learning methods [8]. As for the SVM classifier, it is important to select the right kernel function.

The authors use the nonlinear SVM along with the Gaussian radial basis function kernel in the system. This is because it achieves better results compared with linear and polynomial kernels [8].

In the Experiment results section, other retrieval systems with different decreasing methods (PCA, Kernel PCA, Isomap, and MVU) are compared with the proposed system. Using the same condition, in the four abovementioned retrieval systems, the authors use SVM as a classifier along with the train and test phase being the same as the proposed system.

Experiment Results

In this section, other decreasing methods are briefly described and the results that compare the four retrieval systems with the proposed retrieval system are presented.

To investigate the function of the image retrieval system based on the above mentioned methods, the authors use the COREL image database containing one thousand images. In this database, images are classified into ten semantic groups. The groups are Africans, beach, bus, flower, mountains, elephant, horse, food, dinosaur, and building. The authors express the results of each group with a number. For example, number 1 represents Africans, 5 represents mountains, and etc.

Decreasing Methods

The four decreasing methods used in this paper are as follows:

Principal Components Analysis (PCA) is a linear method for dimensionality reduction, which means that it performs dimensionality reduction by embedding the data into a linear subspace of lower dimensionality [11]. PCA constructs a low-dimensional representation of the data that describes as much of the variance in the data as possible. This is done by finding a linear basis of reduced dimensionality for the data, in which the amount of variance in the data is maximal.

Isomap Classical scaling has proven to be successful in many applications, but it suffers from the fact that it mainly aims to retain pair wise Euclidean distances, and does not take into account the distribution of the neighbouring data points [12]. If the high-dimensional data lies on or near a curved manifold, classical scaling might consider two data points as near points, whereas their distance over the manifold is much larger than the typical inter point distance.

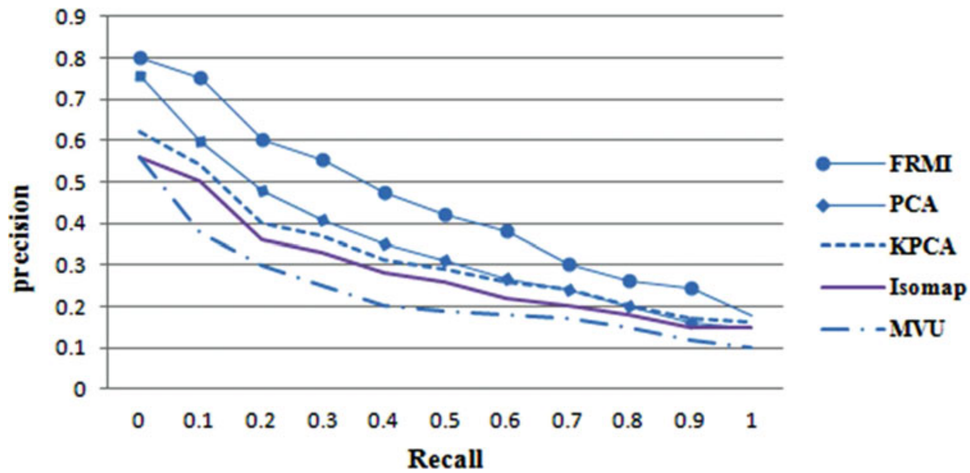

Fig. 2 Precision-recall graph

Isomap is a technique that resolves this problem by attempting to preserve pair wise geodesic (or curvilinear) distances between data points. Geodesic distance is the distance between two points measured over the manifold.

Kernel PCA (KPCA) is the reformulation of traditional linear PCA in a high-dimensional space that is constructed using a kernel function [13]. Kernel PCA computes the principal eigenvectors of the kernel matrix, rather than those of the covariance matrix. The reformulation of PCA in kernel space is straightforward, since a kernel matrix is similar to the in-product of the data points in the high-dimensional space that is constructed using the kernel function. The application of PCA in the kernel space provides KPCA the property of constructing nonlinear mappings.

Maximum Variance Unfolding (MVU) As previously described, KPCA allows for performing PCA in the feature space that is defined by the kernel function. Unfortunately, it is unclear how the kernel function should be selected. Maximum Variance Unfolding (MVU is formerly known as Semi definite Embedding) is a method that attempts to resolve this problem by learning the kernel matrix [14]. MVU learns the kernel matrix by defining a neighbourhood graph on the data (as in Isomap) and retaining pair wise distances in the resulting graph. MVU is different from Isomap in that it explicitly attempts to 'unfold' the data manifold. It does so by maximizing the Euclidean distances between the data points, under the constraint that the distances in the neighbourhood graph are left unchanged i.e. under the constraint that the local geometry of the data manifold is not distorted. The resulting optimisation problem can be solved using a semi definite programming.

Precision-Recall Graph

Recall equals to the number of the related retrieval images to the number of the related images available in images database. The precision equals to the number of the related retrieval images to all the retrieval images [1]. Figure 2 shows the precision-recall graph for ten semantic groups that is used for measuring the efficiency of the proposed retrieval system. In the experiment results the proposed retrieval system is shown as FRMI. From the graph, the authors observe that the proposed retrieval system achieved better results than the other four systems. The reason for this is better algorithm has been applied in the training phase to save appropriate and eliminate useless image features (see Fig. 1). With useful features the system can train the SVM classifier with more accurate rules.

Investigation of the Retrieval Precision

To investigate the total precision of the above mentioned retrieval systems, 1000 images are fed into the system as queried images. The average of the retrieval precision is calculated for each class with relevance feedback and without relevance feedback. Figure 3 shows the results with relevance feedback, and Fig. 4 shows the results without relevance feedback. As expected, the results are better using the proposed system. The average of the retrieval precision with relevance feedback is 75.80 %, 70.43 % and 67.60 % for PCA, KPCA and Isomap respectively, and 63.30 % for MVU. It increases to 80.40 % for FRMI.

The results of retrieval precision without relevance feedback are as follows: 68.20 %, 59.50 %, 56.00 % and 51.80 % for PCA, KPCA, Isomap and MVU respectively. The results jump to 75.50 % for FRMI.

The reasons behind superiority of FRMI because:

1. Rough set theory is a useful method for describing and modelling vagueness in ill-defined environments
2. The use of membership function of a fuzzy set has many advantages in the definition, analysis, and operation with fuzzy concepts.
3. One of the main advantages of using mutual information is it can be used to align images of different groups. It also

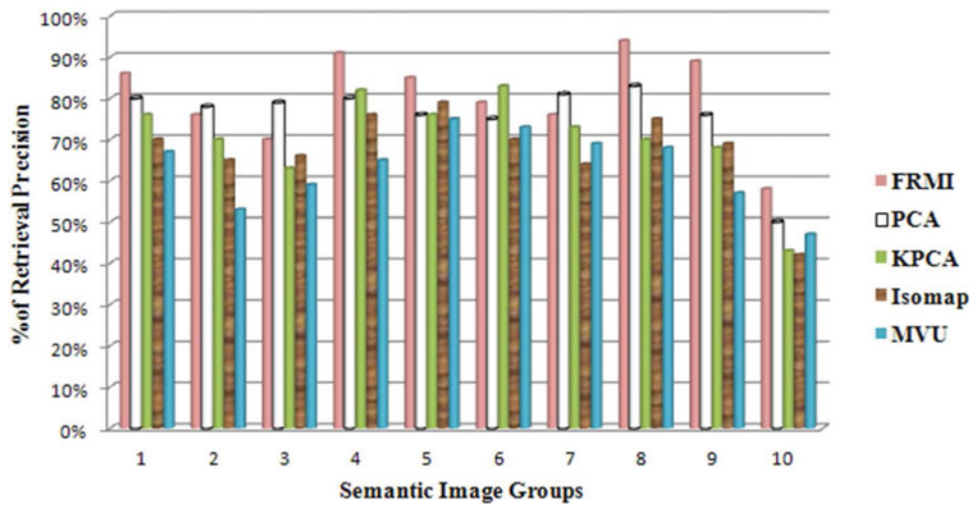

Fig. 3 Precision of retrieval with relevance feedback

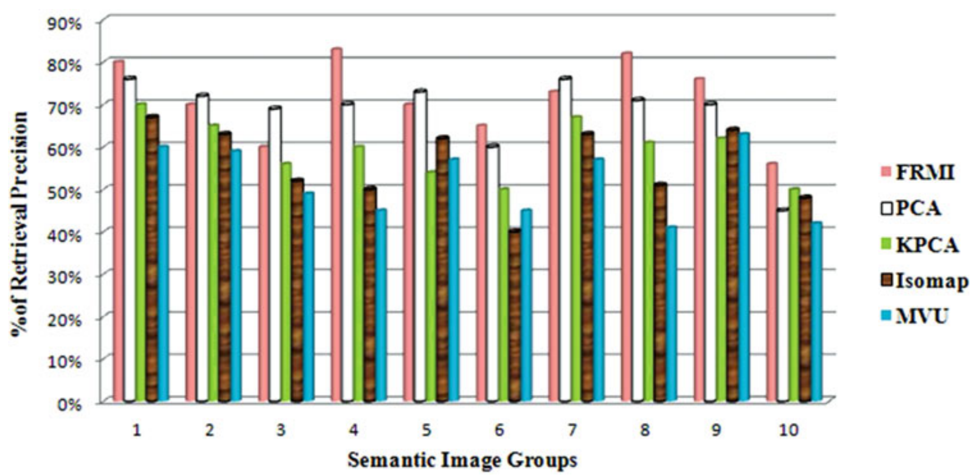

Fig. 4 Precision of retrieval without relevance feedback

requires no decomposition of the data into modes, so there is no need to assume additively of the original variables. It also consumes less computational resources and its parameters are easier to tune.

4. The SVM can perform well with noisier data.

The results achieved with relevance feedback are better than those without relevance feedback. This is because with relevance feedback, user can cooperate with retrieval system and gives his/her opinion directly. This in turn, can help the system to improve the retrieval performance.

Image Comparison of the Retrieval Systems

In the last test, the authors show the retrieval results for the queried bus image (Fig. 5). The first, second, and up to the fifth row in Fig. 6 is related to fuzzy rough set based on mutual information, PCA, Kernel PCA, Isomap and MVU respectively. Referring to Fig. 6, the retrieval system with the fuzzy rough set based on mutual information method more related output images to the user. The first left image in Fig. 6 matched closely to the queried image.

Fig. 5 Queried image

The reason why the proposed method has better results than those in other retrieval systems is that the rules

Fig. 6 Retrieved images according to: first raw-fuzzy rough based on mutual information, second raw-PCA, third raw-Kernel PCA, fourth raw-Isomap, fifth raw-MVU

extracted from features that decreased with fuzzy rough set based on mutual information, are semantic and can better train the SVM classifier. Consequently, the SVM classifier can show more relevant images to user. If the user is not satisfied with the results, with the proposed method, a user does not need to send his/her feedback in long iterations. Users are only required to provide minimum feedback (2 to 3 times) to the system, and the system will then be able to achieve and provide the relevant results to the users.

Conclusion

In this paper, an image retrieval system is proposed. This system used the fuzzy rough set based on mutual information method for feature decreasing and the SVM as a classifier. The system is compared with other retrieval systems that used different methods for decreasing image features. The feature decreasing methods used include the PCA, Kernel PCA, Isomap and MVU. From the experiments results, it can be seen that the proposed image retrieval system has better performance compared to the other four retrieval systems. The drawbacks of these four decreasing methods described in this paper are as follows: (1) In PCA, the computation of the eigenvectors might be infeasible for very high dimensional data, (2) The Isomap algorithm is topologically unstable, (3) The Kernel PCA's kernel matrix size is proportional to the square of the number of instances in the dataset, and (4) MVU has a weakness similar to Isomap. Based on these drawbacks, the four retrieval systems cannot achieve better results than the proposed retrieval system.

By utilising fuzzy rough set theory, the proposed system has the advantage and deal efficiently in image feature environment that is vague and uncertain. In addition, rules extracted from the decreasing features with fuzzy rough based on mutual information are semantic and can train the classifier presciently. An important advantage of this work is training the SVM with semantic rules that can separate the relevant images from irrelevant ones more accurately. Furthermore, by using the relevance feedback, the semantic gap is reduced. The relevance feedback process in the proposed system is not a tedious and time consuming task for the users. Users are only required to provide minimum feedback (2 to 3 times) to the system, and the system will then be able to achieve and provide the relevant results to the users. In conclusion, this proposed system that utilises fuzzy rough set based on mutual information decreasing method, SVM and relevance feedback can achieve better results comparing with other image retrieval systems.

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IR-UWB with Multiple-Access Differential Detection Receiver

Walid Mahmoud

Abstract

Non-coherent communication receivers have simple design, but they always incur bit error rate (BER) performance loss up to $3dBs$ compared to coherent receivers. In this paper, a non-coherent impulse-radio ultra-wideband (IR-UWB) receiver is proposed that supports multiple access (MA) for IR-UWB signals. The signals are transmitted using code division (CD) differential phase shift keying (DPSK) technique. Although UWB is a multipath channel, our proposed communication system is analyzed under additive white Gaussian noise (AWGN) corrupted MA channel to test its applicability. Its average probability of error is derived analytically. Its BER performance is compared against an existing reference coherent receiver. Simulation results are provided to affirm its practicality.

Keywords

Impulse-radio ultra-wideband • Code division multiple access • Differential phase shift keying • Additive white Gaussian noise • Multiple access interference • Bit error rate

Introduction

UWB communication systems are classified either as impulse-radio ultra-wideband (IR-UWB) or multi-carrier ultra-wideband (MC-UWB) depending on their propagated radio [1]. The transmitted IR-UWB signal consists of a series of short-duration pulses of a nanosecond order or even less [2]. Thereby, the energy contained within the signal is spread over a broad frequency range in the available spectrum, namely from $(3.1 - 10.6)GHz$, with very low power spectral density. Because of this, UWB technology can coexist with other existing radio services, experience no fading, attain multi-path resolution, achieve high throughput, and share the spectrum for multiple access.

Although IR-UWB communication systems are intended to work at baseband level, most practical systems still utilize carrier signals [3, 4]. Based on carrier signal modulation, IR-UWB receivers are classified either as coherent or non-coherent systems [5]. On the one hand, coherently modulated carrier signals, using binary phase shift keying (BPSK) modulation, require coherent receivers [6, 7] for demodulation. On the other hand, non-coherently modulated carrier signals, using differential phase shift keying (DPSK) modulation, require non-coherent receivers [8, 9] for demodulation.

In using BPSK modulation, information bits modulate the phase of the carrier signal at transmitter side. Therefore, a carrier recovery circuit (CRC) is required to extract the phase from the received signal, after experiencing the channel effects, for proper demodulation at receiver end, the coherent receiver [10]. The authors in [11] proposed a coherent receiver system in order to improve the bit error rate (BER) performance in countering channel effects. Despite achieving their final goal by using the CRC in the demodulator of their receiver system, the use of CRC has increased the complexity of their receiver system, in terms of hardware requirements.

Alternatively, in using DPSK modulation, the phase differences of information bit signals modulate the carrier

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_25,

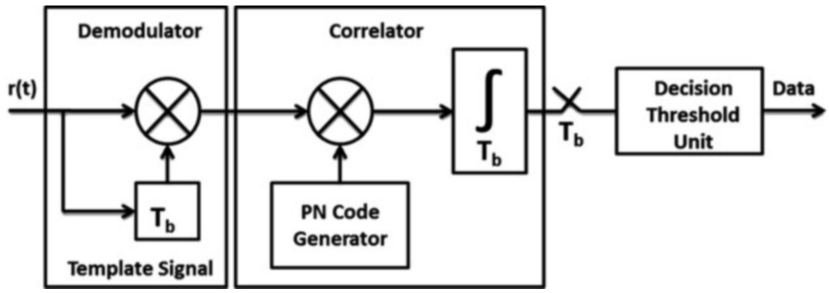

Fig. 1 Conventional differential-detection MA receiver

signal, or in other words, information bits are included within the phase-transitions of the carrier signal. Therefore, a delayed version of the received signal, after experiencing the channel effects, behaves as the template for demodulation without requiring any CRC in non-coherent receivers.

Non-coherent receivers are simple from design perspective compared to coherent receivers, but their BER performance is inferior up to $3dBs$ [10]. The attractive features of non-coherent receivers such as design simplicity and bypassing channel estimation requirement, are the main reasons for proposing our IR-UWB differential detection receiver.

In this paper, we refer to our proposed non-coherent IR-UWB receiver for multiple access (MA) support as CD-DPSK. It is represented graphically and mathematically analyzed to derive its average probability of error. Then, it is compared in terms of BER performance against another existing reference coherent receiver [7] that also supports MA, which is referred to as CD-BPSK. The aim of this comparison is to affirm the practicality of our proposed receiver. Despite the simplicity of CD-DPSK receiver, the obtained results have indicated its inferior BER performance relative to CD-BPSK receiver. However, this BER performance is very promising since it is much less than $3dBs$, the expected performance loss as a result of using differential demodulation of non-coherent receivers.

This paper is organized as follows. In section "Relevant Literature Review", we provide some background on receiver systems. Section "The Proposed System" defines the system model and presents receiver analysis for our proposed CD-DPSK system. Simulation results for both CD-DPSK and CD-BPSK communication systems are presented in section "Simulation Results". Finally, the conclusion is drawn in section "Conclusion".

Relevant Literature Review

Conventional differential-detection receiver for MA support consists of three modules, namely the demodulator, the pseudo noise (PN) correlator and the decision threshold unit (DTU) [12] as shown in Fig. 1. In using DPSK modulation, the transmitted bits are included within the phase-transitions of the carrier signal. Therefore the demodulator does not need to replicate the carrier at receiver end for demodulation. In this case, the template signal necessary for demodulation is represented by the previous signaling interval of the received carrier signal, after passing through the channel, which has a single bit-period (T_b) duration. This template signal can be used to recover the transmitted information signal by comparing its phase with the phase of the current carrier signal over signaling interval of T_b. Depending on comparison result, the transmitted information signal is recovered along with other additive signals, such as the signals of other active users, representing MA interference channel effect, in addition to other signals, representing AWGN channel effect. Such a demodulation is known in the literature as the differential-demodulation [13], which is performed using receiver module, the demodulator, shown in Fig. 1.

The second receiver module in Fig. 1 is the correlator. The correlator simply used to extract the energy contained within the received information signal of the desired user out of other additive signals. In other words, it collects the energy of the information signal that previously spread at transmitter side. Thus, the information signal of the desired user, the one who is currently communicating with the recipient, after correlating it with the PN signal of the same user is boosted, or recovered, while the additive signals experience attenuation and appear as noise signals at correlator output.

Based on correlator output, the DTU, the third receiver module in Fig. 1, detects whether the recovered data signal has value above the threshold, or a value that is below the threshold. Depending on the decision criterion, the output of the DTU is a series of random 1 s and 0 s representing the originally transmitted information bits.

In BPSK modulation, the transmitted bit is included within the phase itself of the carrier signal. Therefore the demodulator does need the carrier-phase to assist in the demodulation. A carrier recovery circuit is necessary for tracking and extracting the carrier-phase from the received signal [14]. In the demodulator, the reference signal that matches the originally transmitted signal, when multiplied by the recovered carrier-phase will produce the locally

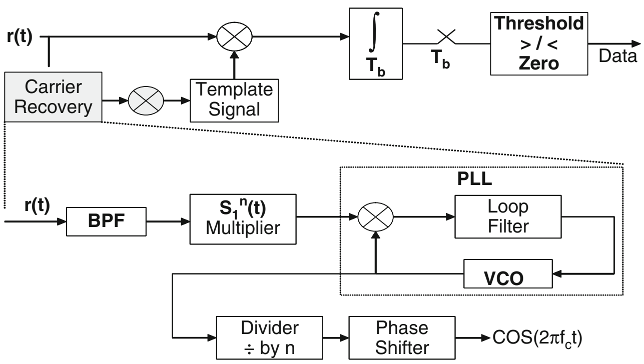

Fig. 2 Direct-sequence BPSK (DS-BPSK) MA receiver

generated template (LGT) signal, which performs the demodulation with the received signal to recover the transmitted information bits. A practical direct-sequence BPSK receiver for MA support is shown in Fig. 2. The additional components necessary for coherent demodulation, such as the carrier recovery circuit, the analog multiplier (mixer) and the reference signal adds design complexity for BPSK receiver. In return, the BER performance of BPSK receiver is better than that of DPSK receiver. The previous fact is the result of using the carrier recovery circuit and the existence of only a single noise-term during the demodulation. The noisy template signal produces a double noise-term in DPSK receivers and reduces their BER performance.

Rake receivers are designed specifically to collect the energy from the scattered multipath components in multipath fading channels. Coherent modulation such as BPSK permits the use of coherent-rake receivers, also known as selective-rake (S-Rake) receivers. S-Rake receivers require full channel estimation, necessary to capture and track the amplitude, delay and phase of scattered components. In addition, S-Rake receiver should implement the selection diversity necessary to combine the collected energy, such that to maximize the signal-to-noise ratio (SNR) metric, therefore, they are complex in their design. Alternatively, noncoherent modulation, such as DPSK, permits the use of noncoherent-rake receivers, also known as partial-rake (P-Rake) receivers. P-Rake receivers do not require full channel estimation and selection diversity, and collect only the energy of a specific number of scattered components based on their sequence of arrival. Those receivers are simple in their design and consume less power [8, 10].

There are some scenarios where the estimation of the multipath fading channel is difficult and cumbersome, in these scenarios the solution is to use DPSK modulation combined with differential-detection scheme to avoid the need for channel estimation requirement [15].

Our proposed receiver is based on differential-detection scheme that previously explained herein. The structure of the proposed receiver has a quite different configuration when compared to receiver structure in Fig. 1, but with somehow comparable complexity when considering the constituent components of both receivers. The proposed receiver can acquire time synchronization with the received signal, but not phase synchronization, therefore, its BER performance is expected to be better than that for the receiver shown in Fig. 1 [16].

The Proposed System

System Model

1) Transmitter: The transmitter in DS-DPSK system is similar to that in [7], except that the information are bit-level differentially encoded and the BPSK Modulator is replaced by DPSK Modulator. Because of this, the transmit signal of DS-DPSK system for the k^{th} user is given by

$$s_{tr}^{(k)} = \sum_{j=-\infty}^{\infty} \sum_{n=0}^{N_c-1} d_j^{(k)} c_n^{(k)} p_{tr}(t - jT_b - nT_c), \qquad (1)$$

whereby $d_j^{(k)} = d_{j\text{-}1}^{(k)} b_j^{(k)}$ for all $b_j^{(k)} \in \{-1, 1\}$ is the j^{th} differentially encoded bit, $c_n^{(k)}$ is the used gold code sequence, $p_{tr}(t)$ is the transmitted 2^{nd} derivative Gaussian pulse, T_c is the pulse repetition period, N_c is the number of pulses per bit and the bit period is $T_b = N_c \times T_c$.

2) Channel: The channel is the additive white Gaussian noise (AWGN) corrupted multiple-access (MA) channel that has two sources of noise. The first source is the receiver noise, denoted as $n(t)$, represented by the additive random noise at receiver input. This noise is modeled as a white Gaussian random process that has zero-mean and variance σ_n^2, i.e., N(0, σ_n^2), with power spectral density equal to $N_o/2$. The second source is the multiple-access interference, denoted as (MAI), represented by the aggregate effect of having more than one active user in the system simultaneously. The MAI is approximated as a white Gaussian random process.

3) Receiver: When there are N_u active users in the system, the received signal can be expressed as

$$r(t) = \sum_{k=1}^{N_u} S_{rec}^{(k)}(t) + n(t), \qquad (2)$$

where $S_{rec}^{(k)}(t)$ is the received signal of k^{th} user at receiver input, and $n(t)$ is the added receiver noise.

Bit-level differential encoding at transmitter side allows for bit-level differential detection at receiver side. In this scheme, the previous signaling interval (i.e., bit-period long) is used to recover the originally transmitted data bit from the

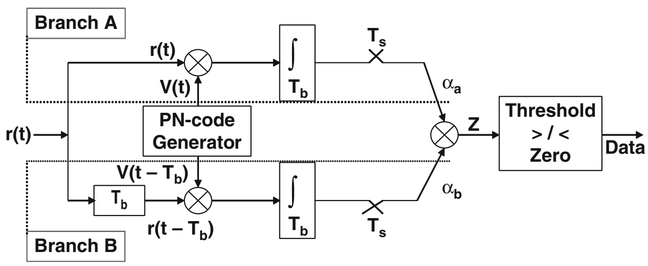

Fig. 3 Proposed differential-detection MA receiver

current signaling interval. Therefore, receiver device should have two branches, namely branch A and B, to represent $r(t)$ and $r(t–T_b)$ as shown in Fig. 3.

At receiver input each user is recognized by a unique Pseudo-Noise (PN) code. The PN Code Generator in Fig. 3 exists mainly to generate the unique code for the user currently receiving data. The variable statistics at each branch, namely α_a and α_b, are the result of correlating $r(t)$ and $r(t–T_b)$ with the desired-user PN code over bit-period. Multiplying α_a and α_b is equivalent to extracting the sign or the phase difference between the current and previous signaling intervals. The decision variable, Z, at the mixer-output is then compared against the threshold to recover the transmitted information bit (data-bit).

Receiver Analysis

In this subsection the variable statistics like α_a, α_b, and the decision variable Z shown in Fig. 3 are analyzed, and expressed mathematically. The expression for the average probability of error in the proposed receiver is derived using the obtained mathematical expressions.

1) Branch A: By referring to Fig. 3 above, the correlator output is given by

$$\alpha_a = \int_0^{T_b} r(t)v(t)dt \tag{3}$$

The assumption hereafter is that user 1 will be the desired user, and we are going to detect the l^{th} data bit. In this case, the template can be defined as

$$v(t) = \sum_{m=0}^{N_c-1} c_m^{(1)} p_{rec}(t - lT_b - mT_c), \tag{4}$$

and the received signal after simplification is expressed as

$$r(t) = \sum_{m=0}^{N_c-1} d_l^{(1)} p_{rec}(t - lT_b - nT_c) + n_s, \tag{5}$$

where $n_s = \sum_{k=2}^{N_u} S_{rec}^{(k)}(t) + n(t)$ is the noise source including MAI and receiver noise $n(t)$, and excluding the signal of the desired user. By simplifying the result of Eq. (3) above, the final expression for the variable statistic α_a is given by

$$\alpha_a = m_a + n_{ar} + n_{am}, \tag{6}$$

where by m_a, n_{ar} and n_{am} are the contributions of the desired signal, receiver noise and MAI at branch A. They are defined as

$$m_a = \int_0^{T_b} \sum_{n=0}^{N_c-1} d_l^{(1)} c_n^{(1)} p_{rec}(t - nT_c) \times \sum_{m=0}^{N_c-1} c_m^{(1)} p_{rec}(t - mT_c)dt = N_c E_p d_l^{(1)} = E_b d_l^{(1)} \tag{7}$$

The term n_{ar} is defined as

$$n_{ar} = \int_0^{Tb} n(t) \times \sum_{m=0}^{N_c-1} c_m^{(1)} p_{rec}(t - mT_c)dt \tag{8}$$

Under the assumption in [15] n_{ar} has zero-mean and variance σ_{reca}^2, where

$$\sigma_{reca}^2 = N_c E_p \sigma_n^2 = E_b \sigma_n^2 \tag{9}$$

The term n_{am} given by

$$n_{am} = \sum_{k=2}^{N_u} d_l^{(k)} \left\{ C_{k,1}^{(0)} \right\} \tag{10}$$

where by $\{C_{k,1}^{(0)}\}$ is the cross-correlation function between the desired and interfering users during the l^{th} bit interval.

2) Branch B: Due to the similarity of the derivations with branch A, except for the bit-period (T_b) delay that should be considered, *only* the final expression for the variable statistic α_b is included here, which is given by

$$\alpha_b = m_b + n_{br} + n_{bm}, \tag{11}$$

where by the right-hand side terms are the contributions of the desired signal, receiver noise and MAI at branch B, respectively.

3) Error Probability (P_e) Analysis: In Eqs. (6) and (11) above, if MAI terms n_{am} and n_{bm} are approximated such that to have Gaussian distribution, then $\alpha_a = m_a + n_a$ and $\alpha_b = m_b + n_b$. By referring to Fig. 3 above, the decision variable $Z = \alpha_a \times \alpha_b$. Assuming that the data bit "1" is transmitted, then the current and previous bits of DPSK signal are the same, hence $m_a = m_b$. Therefore, Z after simplification is expressed as

$$Z = m_a^2 + m_{ab} + n_{ab} \tag{12}$$

Squaring the result in Eq. (7) for the desired signal component m_a at branch A gives

$$m_a^2 = \left(N_c E_p d_l^{(1)}\right)^2 = \left(E_b d_l^{(1)}\right)^2 = E_b^2 \tag{13}$$

After simplifying the derived expressions, the statistics for the second term in Eq. (12) were found to be zero-mean expected value and variance given by

$$var[m_{ab}] \; = E_b N_o + \; 2 \times (K1) \times (E_b/N_c)^2 \tag{14}$$

The statistics for the third term in Eq. (12) were derived using the same scheme as in [9], which is based on Shannon's Sampling theorem. Given β as the bandwidth of transmitted pulse, after simplifying the derived expressions, it was found that n_{ab} has a Gaussian distribution with zero-mean expected value and variance given by

$$Var[n_{ab}] = \frac{2\beta T_b}{cl} \times \left[N_o/2 + N_c^2\right]^2 \tag{15}$$

To consider other active users in the system $Var[n_{ab}]$ should be multiplied by $(K - 1)$. In this work SNR is given by

$$SNR = \frac{m_a^2}{var[m_{ab}] + var[n_{ab}]} \tag{16}$$

Substituting the relevant expressions from Eqs. (13), (14) and (15) in Eq. (16), the final analytical expression for the SNR is given by

$$SNR = \frac{E_a^2}{E_b N_o + 2 \times (K-1) \times \frac{E_b{}^2}{N_c} + \frac{2\beta T_b}{cl} \times \left[\frac{N_o}{2} + \frac{1}{N_c^2}\right]^2} \tag{17}$$

Substituting the obtained SNR in the expression for the probability of error of DPSK receivers in AWGN channel, namely

$$P_e = 0.5 \times \exp(SNR), \tag{18}$$

the final expression for the average probability of error in the proposed receiver is obtained as given in (18) above.

Simulation Results

The results of simulating DS-DPSK and DS-BPSK systems using $Matlab^{TM}$ are presented in this section. Simulation parameters in both systems are identical, such that to have fair and unbiased comparisons. The used $2nd$ derivative Gaussian pulse is defined as

$$W_{tx/rec}(t) = [1 - 4p]\left(\frac{t}{\tau_m}\right)^2]exp\left[-2p\left(\frac{t}{\tau_m}\right)^2\right], \tag{19}$$

where $\tau_m = 0.2\ ns$ and $T_w = 0.5\ ns$. The lengths of the used gold sequences are $cl = 7$, and the pulse repetition period $T_c = 1\ ns$. Therefore, the expected data rates for the proposed system is $R_b = \frac{1}{cl \times T_c} \approx 150Mbps$ per user. In both systems the interferers are 1, 2, and 3 such that the total number of active users under study is 4.

Proposed vs Reference

Performance comparison between both receivers for the required SNR necessary to achieve $BER = 10^{-3}$ for different number of active users are shown in Fig. 4.

From Fig. 4 above, it is shown that the maximum increase in SNR required to achieve $BER = 10^{-3}$ for DS-DPSK receiver is $1.2dB$. Since this value is less than $3dB$—the expected increase in SNR as a result of using noncoherent receivers, the proposed receiver is a valid IR-UWB differential-detector. The slight performance improvement in the proposed system is the result of using gold codes in conjunction with DPSK modulation. Gold codes have noise-like behavior responsible for improving the spectral properties of the transmitted DPSK signal. Also, as a result of the ability to locally acquiring time synchronization between the received and template signals in our proposed receiver structure.

Efficiency of DS-DPSK

To confirm the validity of the proposed system as a MA receiver, a new performance metric called Multiple-Access Efficiency (MAE) has been defined to perform this task. The metric is given by

$$MAE = \left[10^{(SNR_{cc} - SNR_{pc})/10}\right]^{-1} \times 100\%, \tag{20}$$

where SNR_{cc} and SNR_{pc} are defined as follows. By drawing a horizontal line at $BER = 10^{-3}$ in Fig. 5, if the movement is from the intersection point on the single-user graph to the intersection point on the two-users graph, then SNR_{pc} is the value of the first point and SNR_{cc} is the value of the second point. Proceeding in this way while moving from graph 2 to graph 3, and from graph 3 to graph 4, respectively, the calculated MAE values are 45.7 %, 49 %, and 56.5 %. The increase in these values means that DS-DPSK receiver is

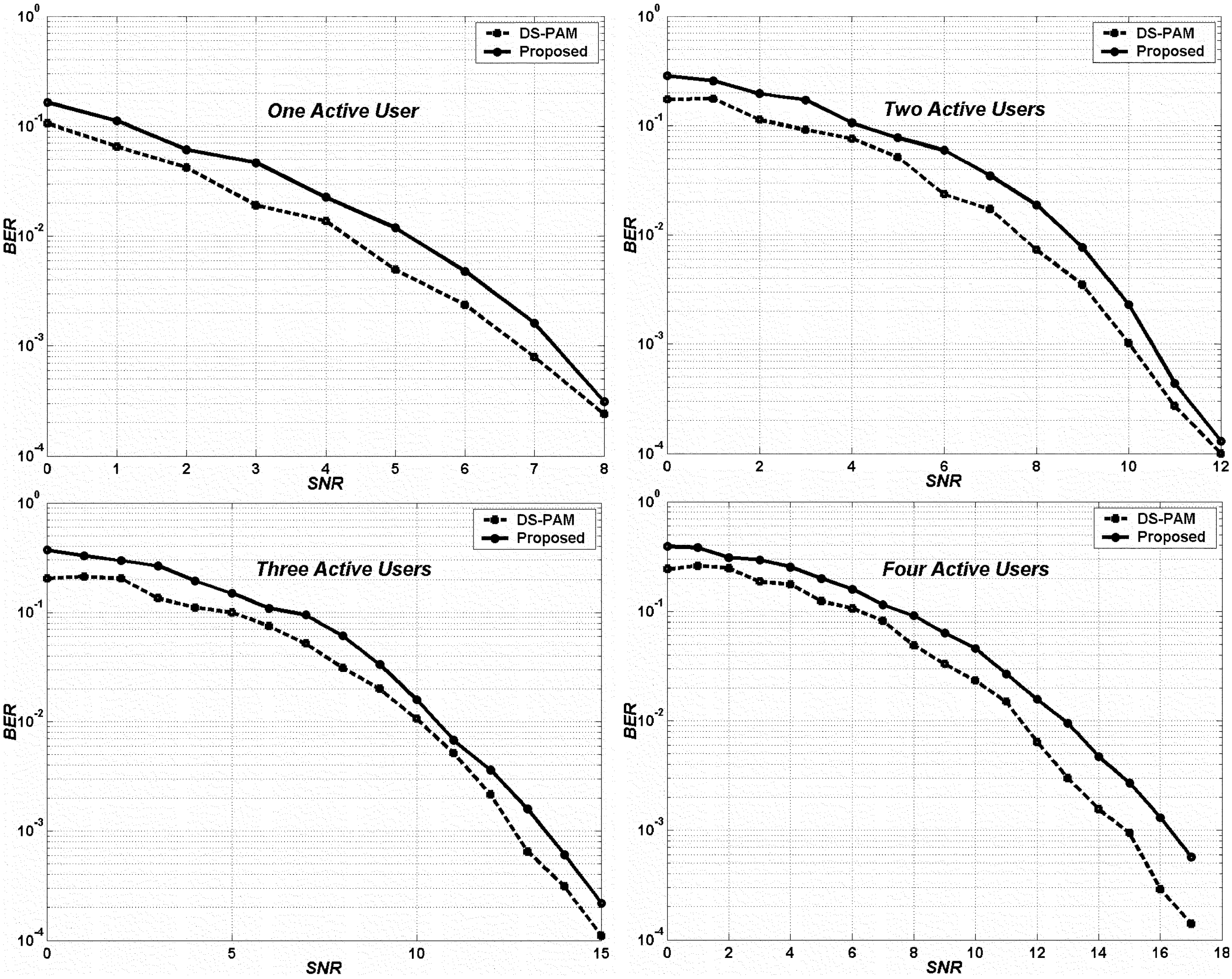

Fig. 4 BER vs SNR (DS-BPSK & DS-DPSK MA receivers)

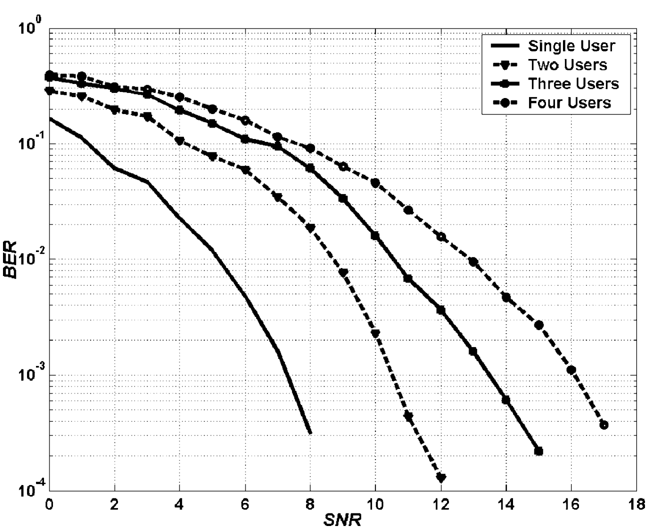

Fig. 5 BER vs SNR (DS-DPSK MA receiver)

capable of handling the increase in the number of active users in the system as long as not reached the 100 % value. Therefore, this performance metric has confirmed the validity of the proposed system as an efficient IR-UWB MA receiver. MAE can be used to define the upper bound for the required increase in SNR, especially when it approaches 100 % value. At this value, the maximum number of active users that DS-DPSK receiver can support is also approached.

Conclusion

In this paper a new non-coherent IR-UWB receiver structure that supports MA was proposed. The system was analyzed over an AWGN corrupted MA channel. Closed-form expression for its average probability of error has been derived analytically. The system was compared against another existing coherent system in terms of BER performance to confirm its practicality. Despite its slight BER performance loss relative to DS-BPSK receiver, as confirmed by the obtained simulation results, its simple design and its ability to relax channel estimation requirements are the main factors for proposing the receiver for IR-UWB communication systems.

Acknowledgment The author would like to warmly thank peer reviewers, either the known of them or those who preferred to be anonymous, for their help in reviewing this manuscript.

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Digital System for the Study of Fast Processes

Florin Grofu and Constantin Cercel

Abstract
Evolution of data processing numeric systems has led to deployment of high performance data acquisition systems. For slow processes are required acquisition systems with low processing speed which are easy to design and implement, but for fast processes required acquisition systems become more complex, with high speed data acquisition and transmission rate.

Keywords
Digital system • Fast processes • High performance • Acquisition systems

Introduction

Many times, in practice, is required analyzes for time variable signals. If the speed of variation of signal analyzed if low, then sample rate is low. This fact leads to possibility to use simple data acquisition and transmission systems to process this information. Achieving an acquisition and transfer rate of 10,000 samples/s can be made with simple acquisition system and a PC with serial port RS232. Considering a 12 bits conversion, equivalent with 2 byte for each conversion, then result a transfer rate of 10,000 samples/s $\times$ 2 bytes $=$ 20,000 bytes/s $\approx$ 200,000 bits/s (considering for each data byte—8 data bits, one start bit and one stop bit). According to Shannon sampling theorem, the high frequency which can be analyzed at 10,000 samples/s is 5,000 Hz, enough for most analyzed processes.

On the other hand, if is required analyzes of fast processes, like vibration analyze, where to analyze signals with frequencies the order of 10 kHz, is required many more samples/s than minimum 2 given by sampling theorem, simple acquisition systems cannot be used. If must analyze a signal with maximum frequency at 40 kHz using at least 25 samples/period result in an acquisition rate at 100,000 samples/s. An acquisition system with 100,000 samples/s rate is not so hard to design. The main problem become the transmission of this data, resulting a transfer rate approximately at 100,000 samples/s $\times$ 2 bytes $\times$ 10 bits/byte $=$ $\approx$2Mbits/s, hard to realize if the system is not connected through DMA to PC data bus. Such acquisitions systems are made as dedicated PC expansion boards.

There are situations where the acquisition system must be placed in industrial environment at distance from PC. Such system is necessary to analyze vibrations on water discharge pomp from coal mining pit. Working environment is not so friendly, especially in situation of defective functioning of equipment's, as in Fig. 1, when the water pomp was flooded. Can be observed that if for acquisition system we have mounting solutions, for a process computer is very difficult to work in this condition.

In this case the used solution is taking into account that the vibration analyses can be made on big period of time, not in real time.

System Background

The new system is based on solution presented in [1] were was chosen to design and develop a fast one channel acquisition system, with local memorizing into a 2 MB RAM

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_26,

Fig. 1 Flooding water discharge pomp

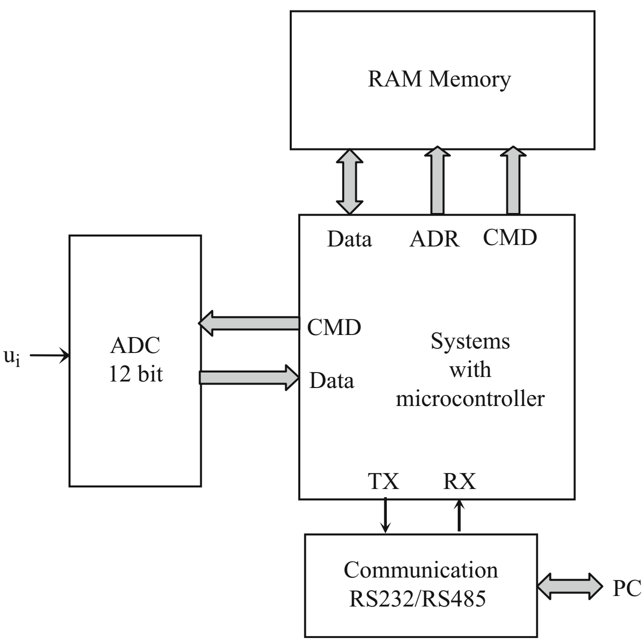

Fig. 2 DAQ structure

memory and later transmission using RS485 communication to industrial computer from nearest electric house [1]. Proposed structure for acquisition system is presented in Fig. 2.

After implementation and testing of the acquisition system result an acquisition speed of 150,000 samples/s. For a 12 bits conversion (2 data bytes) and for a memory of 2 M bytes, result an acquisition time of 7.2 s. Time to download data is about minutes; in this case the analysis of signal can be made on each 30 min, enough for proposed application.

In case if desired a large number of input channels can be used the multiplexing of inputs, as in Fig. 3 [2, 5].

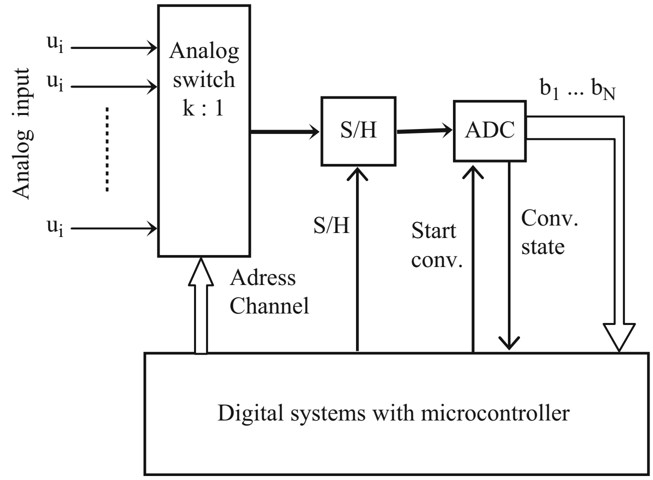

Fig. 3 Increasing the number of input channels

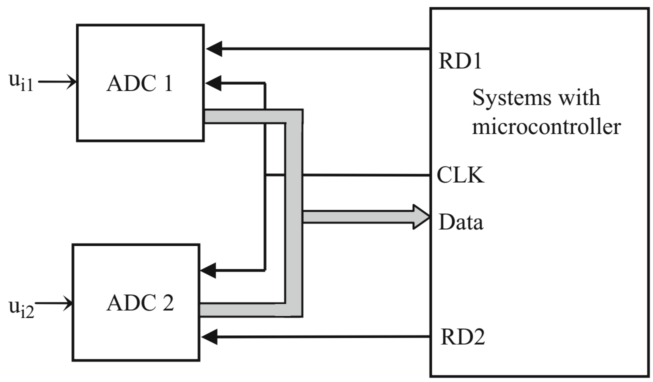

Fig. 4 2-channel DAQ structure

As result of laboratory tests appeared the need to acquire two simultaneous signals to determine the phase shift between this signals. The best solution on high speed signal variation is use of two analog to digital converters, one to each channel, to realize simultaneous the two conversions. The circuit structure is represented in Fig. 4.

Both conversions are made simultaneous, but reading data after conversion is done separately for each converter.

Practical Implementation

The development of the new system start from the system with one input channel, which has structure presented in Fig. 5, and a picture of real system in Fig. 6 [3].

For a versatile functioning of the existing system wanted to find a solution which may transform it into an acquisition system with two channels, but with minimum hardware modification. Modifying the system with one channel for a simultaneous acquisition on two channels was possible due to very flexible architecture designed for initial acquisition

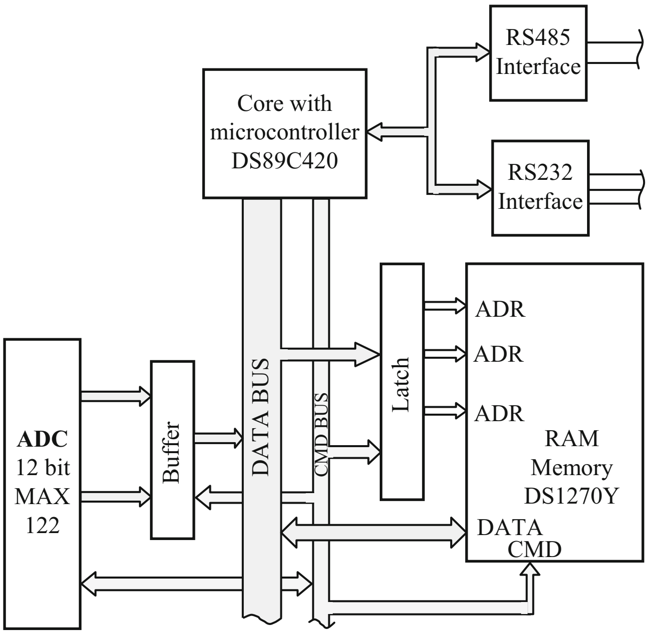

Fig. 5 Structure of DAQ system

Fig. 6 Practical implementation

system and also, due to using of the analog to digital converter MAX120 [4].

The MAX122 is complete, BiCMOS, sampling 12-bit analog-to-digital converters (ADCs) combine an on- chip track/hold (T/H) and a low-drift voltage reference with fast conversion speeds and low power consumption. The T/H's 350 ns acquisition time combined with the MAX122's 2.6 ns conversion time results in throughput rates as high as 333

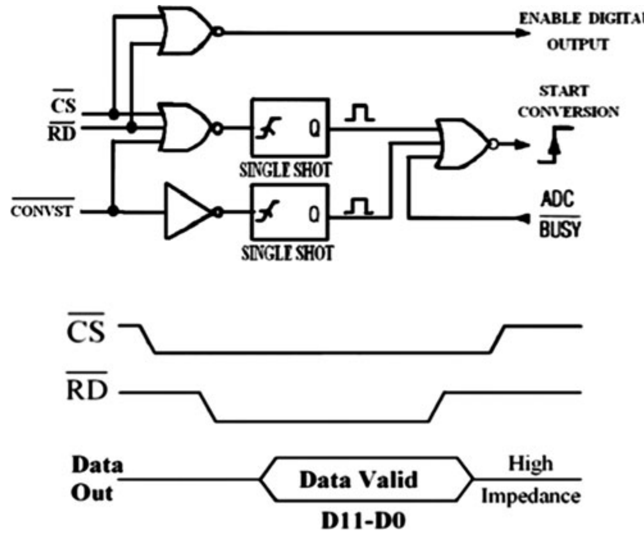

Fig. 7 Conversion—control logic and data-access timing

kilosamples per second (ksps). The MAX 122 accept analog input voltages from −5 V to +5 V. The only external components needed are decoupling capacitors for the power-supply and reference voltages. The MAX 122 operates with clocks in the 0.1–5 MHz frequency range.

The conversion result is output on a 12-bit data bus with a 75 ns data-access time. The output data format is twos-complement. The three input control signals ($\overline{CD}$, $\overline{RD}$, and $\overline{CONVST}$), the $\overline{INT/BUSY}$ converter status output, and the 12 bits of output data can interface directly to a 16-bit data bus.

The MAX 120/MAX 122 has five operational modes. Full-control mode (mode 1) provides maximum control to the user for convert start and data-read operations. Full-control mode is for μPs with or without wait-state capability. Stand-alone mode (mode 2) and continuous-conversion mode (mode 5) are for systems without μPs, or for μP-based systems where the ADC and the μP are linked through first in, first out (FIFO) buffers or direct memory access (DMA) ports. Slow-memory mode (mode 3) is intended for μPs that can be forced into a wait state during the ADC's conversion time. ROM mode (mode 4) is for μPs that cannot be forced into a wait state.

In all five operating modes, the start of a conversion is controlled by one of three digital inputs: ($\overline{CONVST}$, $\overline{RD}$ or $\overline{CS}$). Figure 7 shows the logic equivalent for the conversion circuitry and data-access timing. In any operating mode, CONVST must be low for a conversion to occur. Once the conversion is in progress, it cannot be restarted. Read operations are controlled by RD and CS. Both of these digital inputs must be low to read output data. The INT/BUSY output indicates the converter's status and determines when the data from the most recent conversion is available.

To achieve a simultaneous conversion with minimum hardware changes of existing acquisition system the two

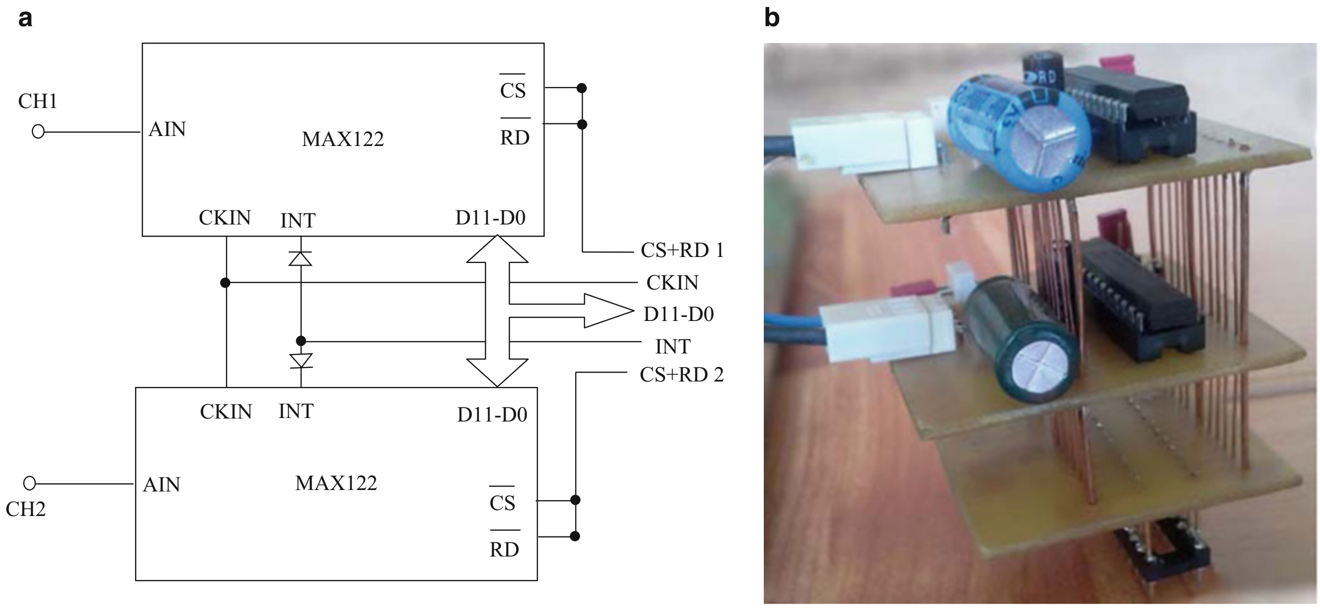

Fig. 8 (**a**) 2-channel equivalent ADC (**b**) ADC—implementation

converters was linked in parallel mode, pin to pin, except two signal inputs and pair pins CS and RD, converters working in mode 3.

The result of this change has equivalent scheme in Fig. 8a, and the real implementation in Fig. 8b with the converters placed one over the other as a tower, without any other changes. In this way, has obtained a flexible system working on one or two channels with simultaneous acquisitions.

To be able to achieve acquisition rates up to 150,000 samples/s was used a microcontroller DS89C420 one of the fastest microcontrollers with 8051 core. DS89C420 is 8051 Pin- and Instruction-Set Compatible and have four Bidirectional I/O Ports, Three 16-Bit Timer Counters, 256 Bytes Scratchpad RAM, 16kB Flash Memory, In-System Programmable through Serial Port, Dynamically Adjustable by Software, 1 clock-per-machine cycle and Single-cycle instruction in 30 ns, Optional variable length MOVX to access fast/slow peripherals, Dual data pointers with auto increment/decrement and toggle select, Programmable clock divider, Two full-duplex serial ports, Programmable watchdog timer, 13 interrupt sources (six external), five levels of interrupt priority [6].

Results

To control de acquisition system and to download and view data was developed a software application in LabWindows/CVI [10, 11] with follow features: control acquisition on one or two channels, download data divided into data blocks, view downloaded data, save on hard-disk, possibility to use zoom function to view detailed acquired signal. In Fig. 9 is presented the application user interface in case of recording signal from vibration sensors when input signal is a square wave signal from an electromagnetic system. Both signals were acquired simultaneous.

The application allow control acquisition on each channel, with availability to acquire data from each channel separately or simultaneous from both channels. After acquisition is ended data are available to download on PC, viewed and saved to further processing. For view are available zoom-in and zoom-out functions, moving focus zone, select input channel. In Fig. 10 is presented just the data between samples 146139 and 151198.

Conclusions

Proposed and implemented system is very useful in analyzing high speed variation signals being able to acquire signals to 150,000 samples/s rate, resulting a 7.2 s acquiring time from one channel or 3.6 s from both channels. View and save functions make this system very useful in research laboratory for the analysis of time variable signals. Decreasing conversion rate can be obtained large period of signal recording, being available for analyze maximum 100,000 samples with 12 bits resolution. Saved data can be processed with other software specialized in numeric signals processing.

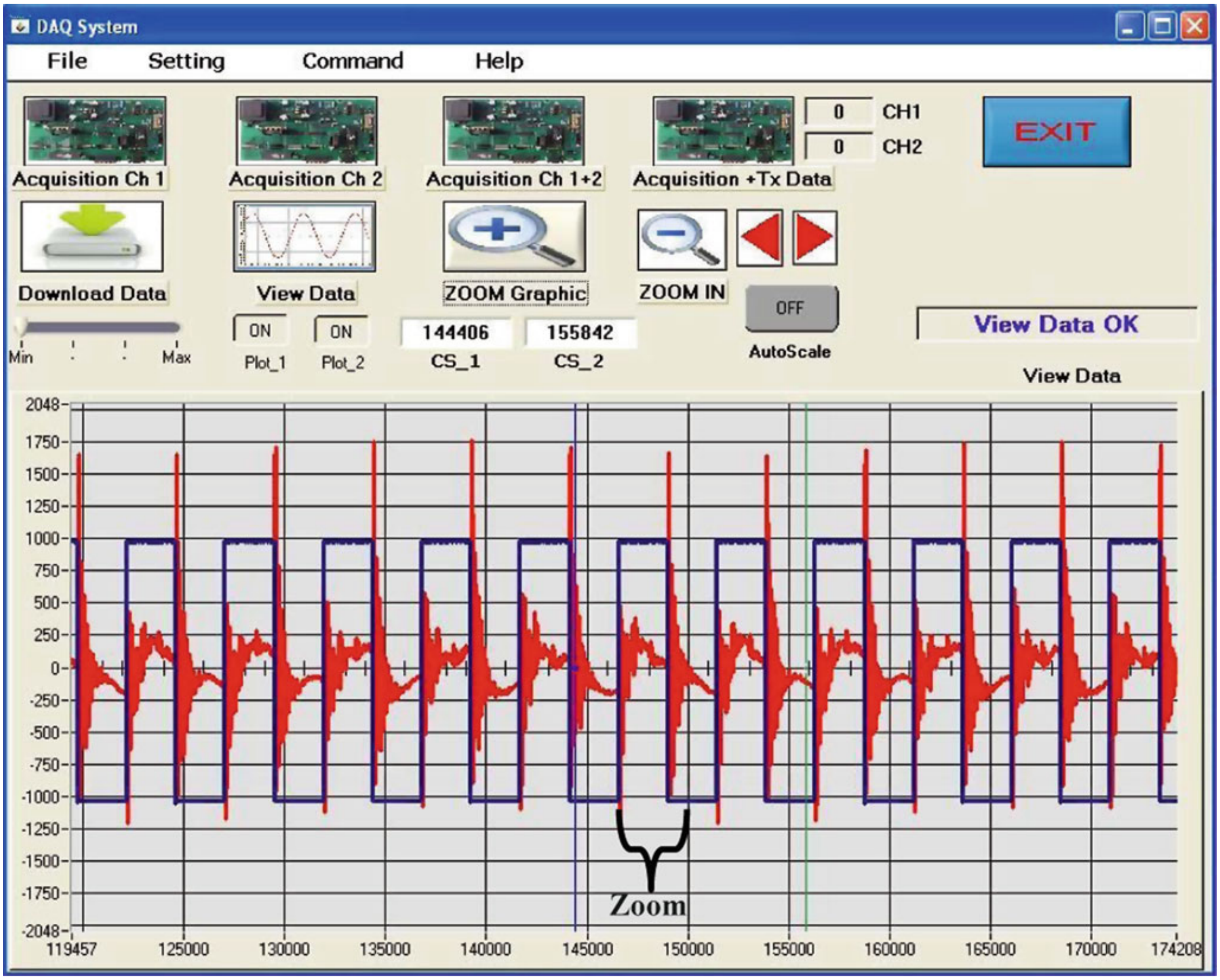

Fig. 9 Experimental results

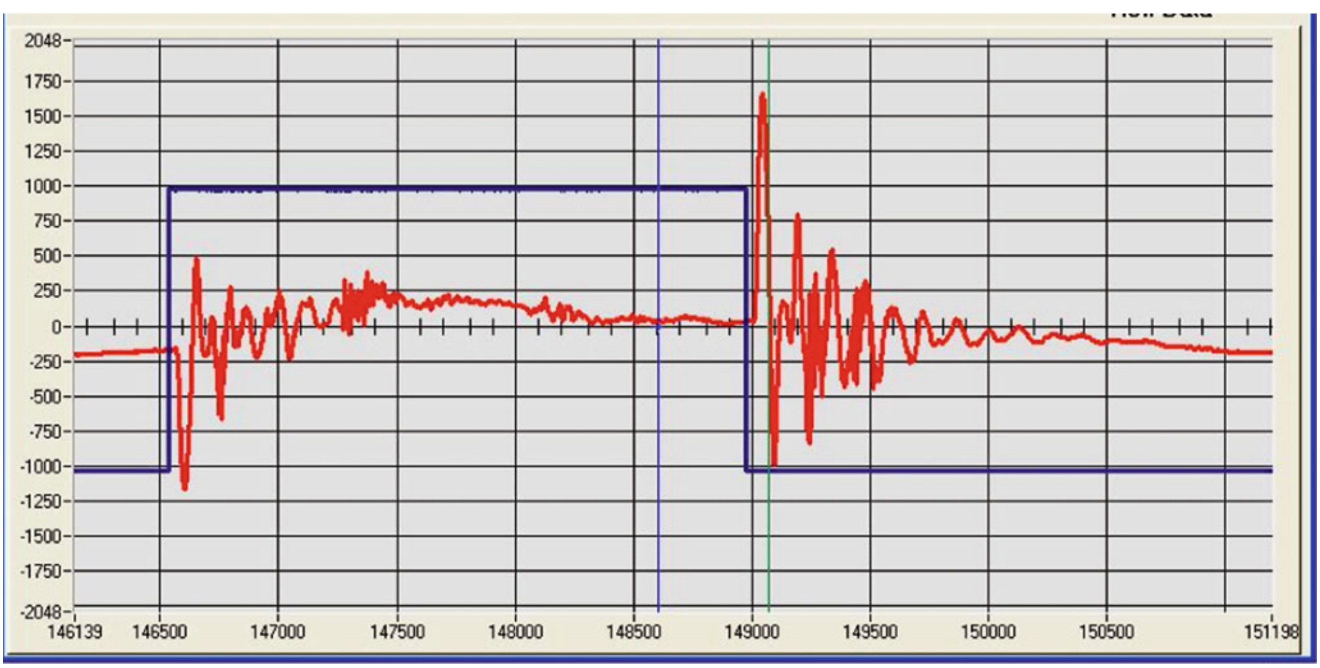

Fig. 10 Zoom function

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A Location-Based Movie Advisor Application for Android Devices

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Abstract

Android is one of the world's most popular mobile platforms. There are more than 600,000 applications available today's market place. Movie advisor applications are also available in Google Play, but there is no location-based movie advisor application for Android devices in Google Play and any other marketplace. A Location-Based Service is a mobile computing application that provides information and functionality to users based on their geographical location. In this study, a location-based movie advisor which is a special application for Android devices to find nearest movie theaters, is developed and implemented. Android devices are getting smarter with new features. By using these devices, we can use new technologies and new ideas. Location-based services are one of these ideas. Wherever you are, you can search and find new possibilities for almost everything. The aim of the location-based movie advisor application for Android devices is to give a brief summary about movies, movie times and also nearest location information of the movie theaters depending on the location of the user.

Keywords

Software architecture • Mobile application development • Android programming • Location-based service

Introduction

In mobile computing applications, a location based service provides services to users based on their location. Geographical location information can be used to find the closest market places or pharmacies and so on. First generation location based services (LBS) were designed as a client-server architecture. For instance, users asked an application for location information and then received a response. In 1996, The White House authorized that selective availability of Global Positioning System (GPS) signals would be phased out [1]. Location based services were standardized by Java Micro Edition Release for mobile platforms which supported Java Platform. With announcement of iPhone, the big revolution in mobile computing came out in June 2007. Almost 1 year later, an Android phone which is known as the greatest rival of iPhone was released by HTC, in October 2008 [2]. Some examples of location based services can be listed as:

- Recommending social events in a city [3].
- Requesting the nearest business or service, such as an ATM or restaurant.
- Turn by turn navigation to any address.
- Locating people on a map displayed on the mobile phone.
- Receiving alerts, such as notification of a sale on gas or warning of a traffic jam.
- Location-based mobile advertising.
- Asset recovery combined with active RF to find, for example, stolen assets in containers where GPS would not work.

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_27,

- Games where your location is part of the game play, for example your movements during your day make your Avatar move in the game or your position unlocks content.
- Real-time Q&A revolving around restaurants, services, and other venues.

In Android platform, there are two kinds of location-based services. One of them is "Android's Network Location Provider" and the other is "GPS utilization". GPS is more accurate than network location provider. However it is convenient for outdoor usage only. It also consumes battery power and has got latencies. Android's Network Provider uses Wi-Fi signals. It works indoors or outdoors, uses less battery power and return the location information as quickly as users want [4]. In practice, a programmer can use both GPS and Android's Network Providers.

There are several problems for obtaining user's location from a mobile device [5]. Reasons are

- multitude of location sources,
- user movement,
- varying accuracy

Next generation location-based services provide additional benefits for users and service providers. There is an explosive growth in the LBS market over the coming years. Apart from the consumer market, there is a good potential for this technology to find its application in many industries including health, manufacturing, mining and financial services [1].

This study is related with a location-based movie advisor application for Android devices which aims to give brief summaries about movies, movie times and also nearest location information of the movie theaters depending on the location of the user. The rest of this paper is organized as follows. In section "Project Specifications", we explain the project specifications and then in section "Determination of Requirements" we determine project requirements. So, we give the all details of software architecture design stages and propose a new location-based mobile application in section "Three-Tier Software Architecture for Proposed Location Based Movie Advisor". In section "Implementation", we show the key idea and implementation steps. In section "Complete System Architecture", we present the complete system architecture, and conclusions are then given in section "Conclusions".

Project Specifications

In this paper, the aim is to develop a location-based Android application that give a brief summary about movies, timetables of the movies and also nearest location information of the movie theaters depending on the location of the user. Briefly, the location-based movie advisor shows the movie theaters according to distance in mobile phones and tablets. This application is called as Cinephilia (love of cinema). Cinephilia has the following specifications: "Cinephilia considers only information for movie theaters of shopping centers in Istanbul-Turkey. Cinephilia considers only today's movies. Cinephilia provides movie times, brief summaries, rating scales of movies, and location of movie theaters."

In today's technologies there are some movie advisor software and web sites are available, but Cinephilia has significant differences. When users start using Cinephilia, their location is determined according to their area. According to this location information, Cinephilia shows nearest movie theaters of shopping centers in Istanbul. In addition, users can learn today's movies and upcoming movies, and users can search movies and get brief information about movies, location of the shopping centers, contact information of movie theaters and finally rating scales of movies and links to movie trailers. Moreover, users give rates to movies, and users get information about the cast. Finally, we can say that Cinephilia has a user friendly graphic user interface and screen transitions.

Determination of Requirements

System Requirements

Cinephilia is an application for Android devices, so it is necessary to use a smart phone or a tablet with Android 2.2 operating system or higher version. Android device should be connected to Internet using IEEE 802.11b/g/n or 3G MSDPA. Android device should have minimum 2Mbyte of free memory and 320×480 pixels screen resolution with 3.5 in. screen.

User Requirements

Wi-Fi or 3G Internet connection should be started up by the users. The application should be started by the users. The users can see all the names of movie theaters and its movie times in Istanbul shopping centers as a list. The users can follow future programs. The users can see name of movie theaters when they permit to determine their location.

Three-Tier Software Architecture for Proposed Location Based Movie Advisor

Cinephilia is the three-tier software architecture as shown in Fig. 1. It is a total solution for accessing all information about movies and it is for people who are interested in

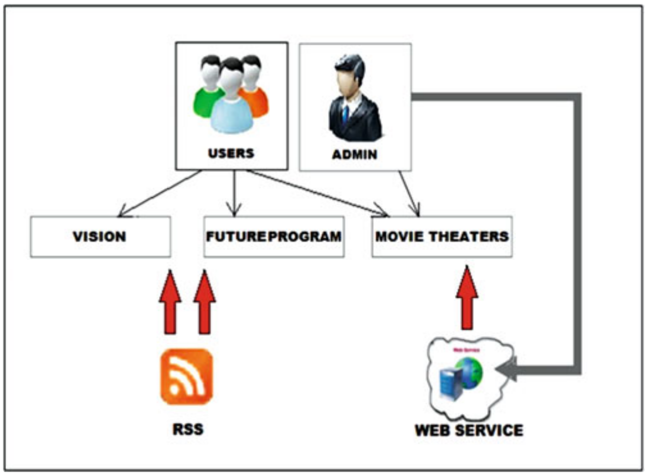


Fig. 1 Three-tier software architecture for location-based movie advisor

movies. Cinephilia includes different sections which are VISION, FUTURE PROGRAM, and MOVIE THEATERS for all users. These sections are independent from each other. There are two different type of User in Cinephilia application.

These are System Administrator and Application Users. The software includes JSON web service and a web feed which is a RSS feed. Web service and RSS feeds provide to access easily actual movies and movie theaters data to users.

System Administrator writes the web service. Administrator can add new movie theaters to web service. System Admin assigns an ID of each movie and adds names of the movies and location of movie theaters according to latitude and longitude variables into web service. Page contents are created according to all cinema ID's in web service. Every content page include only one cinema ID and the page include information about movies and session hour according to this cinema ID. Admin has authority that adding new movies or deleting movies and information about movies. User can see all steps of application. However they cannot do any changes to the movie theaters. Use case diagram of the Location-based Movie Advisor is shown in Fig. 2.

There are several steps for program execution. When Cinephilia splash screen is opened, users see elephant photo with toast message which is "Loading". In totally, splash screen is appeared 18 s and "Loading" toast message lasts 5 s. While these were on the screen, a melody is playing at the background. After finishing the splash screen, the vision page is now open with three tabs which are on the top. While these applications are working, two RSS are parsed in behind. Also, application includes simple web service with xml and http. It is easy to convert web services from web applications. Then, two web services are found for application. For the first address for visions; http://rss.beyazperde.com/movieler/bunlar?format=xml and for future program is founded http://rss.beyazperde.com/movie-ler/buhafta?format=xml address. We have to parse the xml. There are three tabs for users that are vision, this week and cinema halls. All transactions are described in the following section.

Vision Screen

Vision screen which is given in Fig. 3 is the first tab for our application and shows users to see past and present movies in vision. In this screen, the user has a chance to see more detailed information about movies such as movie subject, director name, player name, duration time and its type. Output screen is as follows:

1. If vision screen is requested to open, user should touch vision page from first page screen.
2. When users want to achieve more information about movies which are movie subject, date display and players, they should select any movie and click on it. Then, detail page is opened.

This Week Screen

The user can follow the information about current movies information on this week screen page. By using this screen, wide information obtained from a page which is opened after clicking any movie which you select. Explanations for the subject of the movie, director's name, cast (players), duration time and its type are seen in this page. Output screen is as follows:

1. If this week screen is wanted to open, user should click this week page from first page screen.
2. When users interested in any movie and want to see more information about movies which are subject of the movie, date displayed and players, they should select any movie and click on it. Then, detail page is opened.

Movie Theaters Screen

When the user clicks "Movie Theaters", several steps are achieved in the background. Firstly, latitude and longitude of locations, positions of the users, are listed in the screen. Names of the movie theaters are shown with their IDs and longitude and latitude values which are we entered from http://cineapi.herokuapp.com/theatres address for users can see them. Then, http://cineapi.herokuapp.com/theatre/1/can check the information about movie times and movies which parsed from the web page of sinemalar.com. After that, users

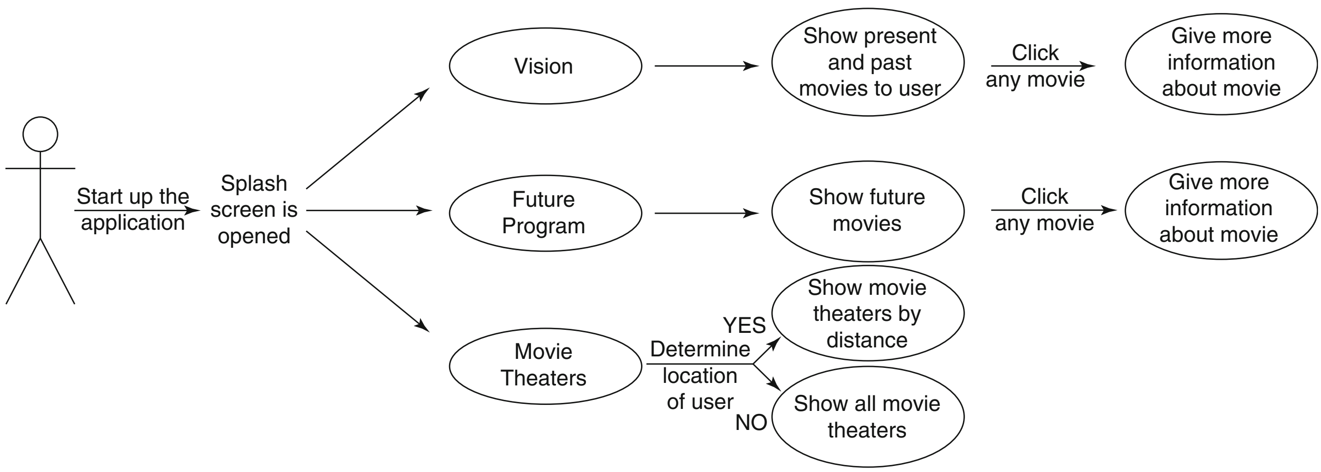
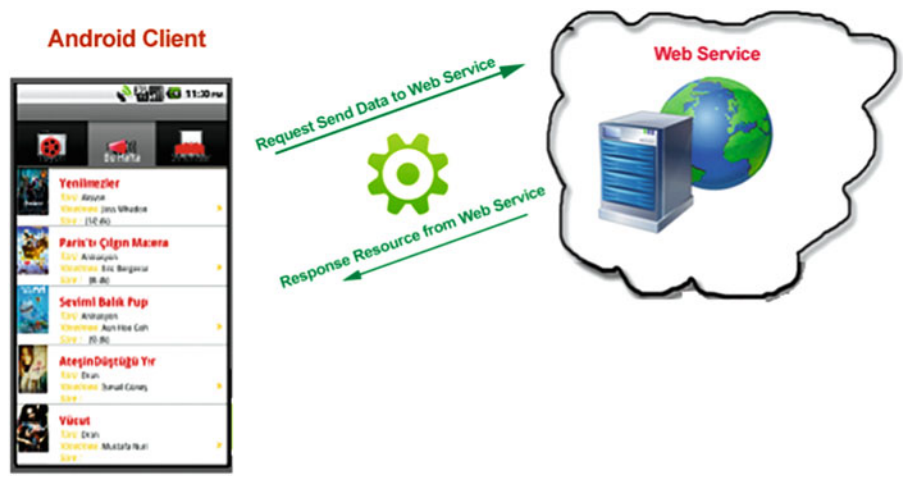


Fig. 2 Use case diagram of location-based movie advisor

Fig. 3 Vision screen and request-response representation to web service



click to any movie theaters which are very close to the users, they can see vision movies.

Movie advisor applications are preferable from a lot of people in today. There are lots of different types applications are also available in today's market for the same aim. Different from other applications, we create this application not only for the "best" provider. We want to make a difference at sector and do whether before in and is collected all the other properties in the same Android system. There are several reasons why our location movie adviser system should be preferred.

Priority to the User's Requests

System identifies, learns and understands user who has got authority in cinema determination and eliminate the cinema which has never want to go. So user decision is very important, and the software behaves regarding user's decision and request.

User Friendly

The architecture of the system is designed in a noncomplex infrastructure to use comfortably in the application. Screen transitions are so easy to users, so users can find whatever they want to see about movies.

To Be Faster

The system has been designed to ensure that users will not wait more and find information as soon as they expect. Application start-up time, determination of movies lists according to location of the users and movies that users may be curious about are archived easily by proposed architecture.

Changeable

The advantage of this system is that, it is to be developable and replaceable so it could open innovation at the android market.

Having a Wide Range of Information

When user starts using this application, their location is founded according to their area. Then, according to location information of users, system shows them movie theaters which are at shopping centers in Istanbul and seasons which is nearest to them. In addition, user can learn today's program and upcoming movies, movie content, the location of the movie theaters and contact information of the movie theaters and movie trailers.

Web Based

If mobile phone or tablets of the users have android system, downloading and installation the application is so easy. It is not necessary to search this program throughout the Internet or give money to download it so users reach it easily whenever they want.

Implementation

In this section, we have a close look to implementation of Location-based movie advisor application. We explain design steps and give the flow chart of the application. Real Simple Syndication (RSS), Web Service, Photoshop CS 5.5, Eclipse IDE for Java Developers, and Pyhton are used for developing the application of Location-based Movie Advisor [6–10]. Explanation of the Algorithm in details is given below.

Cinephilia is considered as a location-based application and it has got two main parts. First part is a web service which stores longitude-latitude (as a pair) information of movie halls in Istanbul and movie's time table. The other part is client part on an Android mobile device. The client device has to have a powerful Wi-Fi connection because it must communicate with the web services. Thus, the application uses Android's Network Location provider.

First of all the client application listens to location updates only while in the running state to minimize the battery consumption. Because of that, the client connects to the Internet at the beginning of the Android application life cycle. The client gets the location information of the user using Wi-Fi connection and tries to find the closest longitude-latitude pair comparing to that information. In order to perform that, the application gets a list from the web service. However it does not need to search entire list because the application can eliminate the other possibilities using client's location.

Secondly, we get the system date and then check the candidate's movie times. Then Cinephilia finds movies which will be shown in that time. According to screen independent Android layout objects, the application lists the movie information. The client application disconnects the Internet when the user kills the process. If the user never kills the process, our application continues to listen to location updates.

Flow chart of location-based movie advisor application is given in Fig. 4. Two main parts of the application can be seen, and also main steps can be described in the flow chart. Cinephilia is considered as a location-based application and it has got two main parts. First part is a web service which stores longitude-latitude (as a pair) information of movie halls in Istanbul and movie's time table. The other part is client part on an Android mobile device. The client device has to have a powerful Wi-Fi connection because it must communicate with the web services. Thus, the application uses Android's Network Location provider.

Our system is created in a non-complex and easy design by using lots of important technologies at the below.

Parsing the Data

Firstly, the searching of web services is started to parse the data. Web services can convert your application into a web-application, which can publish its function or message to the rest of the world. The basic web services platform is xml plus http. We use two web service pages, these are http://rss.beyazperde.com/filmler/bunlar?format=xml and http://rss.beyazperde.com/filmler/pekyakinda?format=xml. Then we parse these xml pages.

TabHost Layout

Secondly a TabHost Layout is created and then four Activities embedded to four Tabs. Three tabs include a ListView. Vision and Future Program and Saloons pages have Listviews.

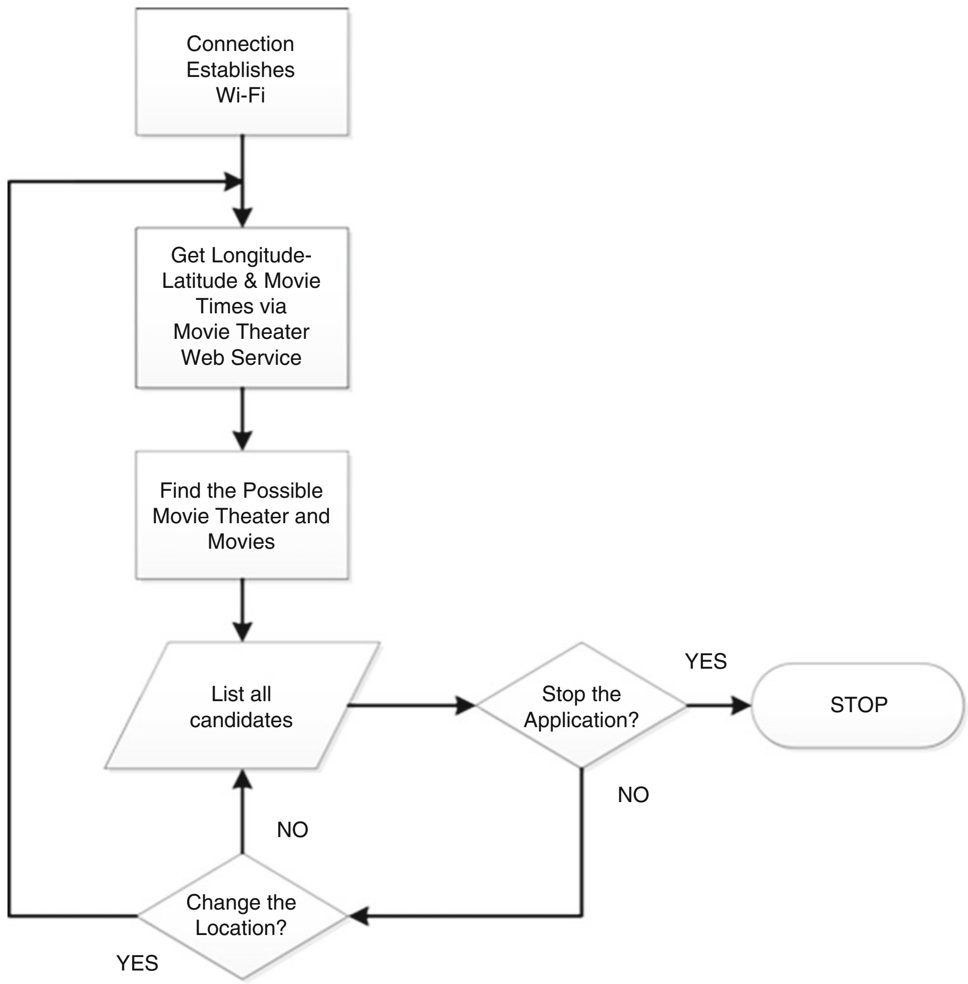


Fig. 4 Flow chart of a location-based movie advisor application for android devices

AsyncTask Thread

Three tabs of program have AsyncTask thread. AsyncTask enables proper and easy use of the UI thread. This class allows to perform background operations and to publish results on the UI thread without having to manipulate threads and/or handlers. Our program shows "Loading" message with AsyncTask thread. An asynchronous task is defined by a computation that runs on a background thread and whose result is published on the UI thread. An asynchronous task is defined by 3 generic types, called Params, Progress and Result, and 4 steps, called onPreExecute, doInBackground, onProgressUpdate and onPostExecute.

Custom Adapter

Custom adapter is utilized list to parsing data. BaseAdapter is an array of arbitrary objects. By default this class expects that the provided resource ID references a single TextView. If you want to use a more complex layout, use the constructors that also take a field ID. That field ID should reference a TextView in the larger layout resource. However the TextView is referenced, it will be filled with the toString() of each object in the array. You can add lists or arrays of custom objects. Override the toString() method of your objects to determine what text will be displayed for the item in the list. ImageViews results fill the views, override getView to return type of view.

LayoutInflater

We use LayoutInflater. Instantiates a layout XML file into its corresponding View objects. It is never used directly. Instead, use getLayoutInflater() or getSystemService(String) to retrieve a standard LayoutInflater instance that is already hooked up to the current context and correctly configured for the device you are running on.

RssHandler

RssHandler class is created to parse images. Because we did not parse images in <enclosure url:> tags. So we use DefaultHandler and SaxParser.SaxParser. These define the API that wraps an XMLReader implementation class. However this interface was replaced by the XMLReader, this class wrapped the Parser interface in JAXP 1.0. For ease of transition, this class continues to support the same name and interface as well as supporting new methods. An instance of this class can be obtained from thenewSAXParser() method. Once an instance of this class is obtained, XML can be parsed from a variety of input sources. These input sources are InputStreams, files, URLs, and SAX InputSources. This static method creates a new factory instance based on a system property setting or uses the platform default if no property has been defined. The system property that controls which Factory implementation to create is named "javax.xml.parsers.SAX ParserFactory". This property names a class that is a concrete subclass of this abstract class. If no property is defined, a platform default will be used. As the content is parsed by the underlying parser, methods of the given HandlerBase or the DefaultHandler are called.

Listview

Each Listview's subtitle has an image a title and subtitles. And we use OnClick event for every subtitle of Listview in the Vision and FutureProgramme pages. If users click to Subtitles, they can see movie's details.

GetListfromXML Methods

ListfromXML methods are used to parse Xml data and the data is embedded to empty text views.

DocumentBuilder

It defines the API to obtain DOM Document instances from an XML document. Using this class, an application programmer can obtain a Document from XML. An instance of this class can be obtained from the newDocumentBuilder () method. Once an instance of this class is obtained, XML can be parsed from a variety of input sources. These input sources are InputStreams, files, URLs, and SAX InputSources.

JSON Object

Our customized HTML data to JSON Object are converted. Then we create a JSON service from on Internet for Movie Theaters. We take JSON data from JSON service and we hold these data in a class. We will hold all JSON data in a class. Also JSON data have Saloons' names, Saloons' latitude and longitude variables. Movies' Names and Sessions are included by Movie Theaters.

Location Manager

The aim of the Location Manager is to find current location of the users. When program find the location of the users, it searches all latitude and longitude variables of movie theaters. If the radius of the current location of user covers the radius of the latitude and longitude variables of the movie theater, the movie theater is listed. Finally users can see all movies in the Vision and Future Program, and they can see the nearest movie theaters and movies belonging to these movie theaters and also they can follow movie times from this application.

Complete System Architecture

People usually prefer to go shopping centers. Shopping centers' number is becoming increase day by day so people can come across them anywhere. They usually want to go to the movies in shopping centers after eating and shopping. Cinephilia application is addressed to people who love movies. It includes all shopping center cinema malls' information in Istanbul and provides them with information about their location after their location search. There are several tabs and programs are used in this application, these are vision, this week and movie theaters.

There are several steps for program execution. Firstly, a splash screen will be opened and the user interface comes to it. There are three tabs that vision, future program and cinema halls are seen in the screen while user interface is started to work. If user clicks the cinema halls tab, notification bar comes to screen and asked to user they can be determined user's location. If user accepts it, the movie theaters from near to far are listed to user. In addition, movies and movies times are seen from chosen movie theater. After clicking the vision tab, vision movies and their directors, duration, type, and posters are informed to users. User can get more information about movies when click any movie they wish.

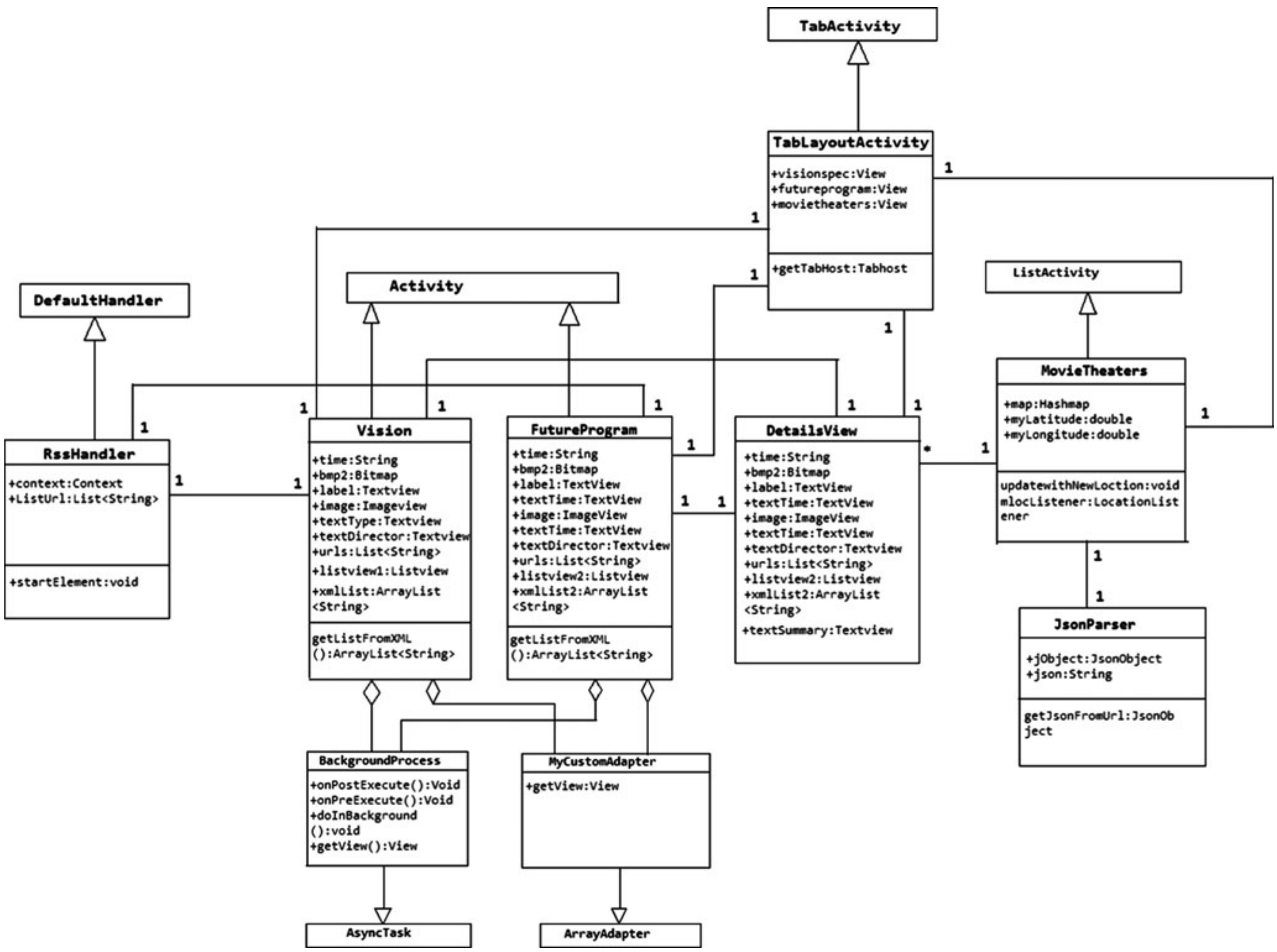


Fig. 5 Software architecture of location-based movie advisor

When future program tab is selected, today's movies and directors, duration, type, and posters are informed to users like vision tab and users learn more information after clicking any movie.

Furthermore, Parsing the data, TabHost Layout, AsyncTask thread, Custom adapter, Listview, LayoutInflater, GetListfromXML methods, DocumentBuilder, JSON object, Location Manager, RssHandler, LayoutInflater are used remarkable Technologies for Cinephilia. Complete software architecture of Location-based Movie Advisor is given in Fig. 5.

Conclusions

Location-based applications are significantly different from any ordinary applications for mobile devices. While a great amount of application has been developed for mobile application, a very few application have been uploaded to mobile markets. Cinephilia is one of the few location-based applications developed for Android devices. Cinephilia firstly determines the location of the users and lists movie theaters to them, so it simplifies the lives of users who go to shopping centers and want to go cinema easily and quickly. Moreover, it shows the most recent movie times so users can go and buy their tickets. In addition, Cinephilia give information to users about movies whatever they want such as director name, movie subject, and movie times, type and cast.

Cinephilia is a simple, non-complex, understandable and attractive. It is designed according to requests of users. While developing Cinephilia, some important design criteria such as user-friendliness, easy to use, and new technologies such as parsing movie information, determination of longitude and latitude of the user are considered.

Briefly, a location-based movie advisor application for Android devices is developed, implemented and explained. We believe that location-based applications will be important part of mobile devices. So, developing this type of application gives a significant contribution to the mobile market. Next generation location-based application development will be potential area for further study of us.

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Eye Tracking and Head Movements Detection to Assist People with Disabilities: Unveiled

Amer Al-Rahayfeh and Miad Faezipour

Abstract

Many researchers have been devoted in the past two decades to develop technologies that assist people suffering motor disabilities associated with problems in verbal communication. Eye tracking and head movement detection and their use in empowering people with disability have remained interesting subjects especially in the current digital era. Generally, eye tracking involves manipulation through measuring the eye motion or monitoring the activities of the eye. Various researches have used different methods of eye tracking providing evidence that the science is of value to the society in general, and to the disabled individuals, in particular. Their methods have worked with individuals as well as groups. Head movement detection tracking has been found to be a natural way of expressing direction, and as a control technique it has been shown to be simple and effective. This paper surveys the literature on eye-tracking and head movement detection techniques for helping the disabled group.

Keywords

Eye tracking • Head movements • Detection • Disabilities

Introduction

With the growing use of computers, the quality of our lives and even the whole society is dramatically changing. Unfortunately, people with disabilities cannot enjoy benefits provided by computers as able-bodies people on equal term since conventional computer interfaces are designed with the able-bodies in mind [1]. Therefore, how to lower or even tear down the barriers between computers and people with disabilities is a demanding task. Recently, advances in hardware and software have led to assistive technology systems that allow people with disabilities to use their limited voluntary motions to communicate with family and friends, access computers, and control the TV and air conditioner, and other systems [2]. Each system has its own considerations, applicability and limitations.

Eye tracking and head movements detection have been used to allow disabled people to use computer facilities. This is important since they are not marginalized in this new technology. An eye mouse has been investigated by many interested groups in related fields as a vital facility in eye tracking as a way of giving the disabled people a chance to use computers. A well designed eye mouse works by letting the eyes manipulate a computer. In designing this, Su et al. [3] uses a computer and web camera providing tremendous results. In this method, a five stage algorithm was explained where the work concurs with many others an aspect that helps in estimation of the directions of eye movements. In the same manner, head movements detection has also received similar attention providing computer interface and the ability to control various devices such as a wheelchair where the position of the head is mapped into control signals of the direction and speed of the wheelchair [4].

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_28,

Literature Relating to the Eye Tracking and Head Movements Detection

From the work of Zhu and Ji, it is realized that eye gaze expresses the interest of a user [1]. This is the gist in use of eye tracking to help people with disabilities. All that should be set is an eye gaze system. It will then track the movements of the eyes of the person who is using the computer. Generally, there exists a range of potential applications of eye tracking systems. They include drivers' fatigue detection systems and learning emotion monitoring systems [5]. Many traffic accidents are due to drivers fatigue or inattention. Lowering the number of accidents that are due to the aforementioned two factors would not only reduce personal suffering but also greatly decrease society cost [6].

In addition to the aforementioned applications, an eye tracking system can be applied to help people with severe disability to manipulate computers (see Fig. 1). Among so many useful assistive technology systems, the "camera mouse" system deserves to be particularly mentioned. Figure 2 shows the image frames of the eye that would be captured by a camera. The system tracks the computer user's various body features for instance the nose, lip, thumb, and the whole eye among others [1]. Tracking is done with a video camera and eye gazes are then translated into the movements of the mouse pointer on the screen. Another mouse-imitating system is Gyro-Mouse which uses gyro sensors for detecting user's head movements and maps those movements into mouse moves and clicks [8].

Other systems designed to assist the disabled are hands-free wheelchairs; those controlled by eye tracking where the direction of the eye gaze is mapped into commands to move the wheelchair. These wheelchairs have been developed to allow safe and easy independent mobility for the disabled [9]. Wheelchairs have also been controlled by head movements. Joseph and Nguyen proposed a telemetric system for replacing joystick control [10].

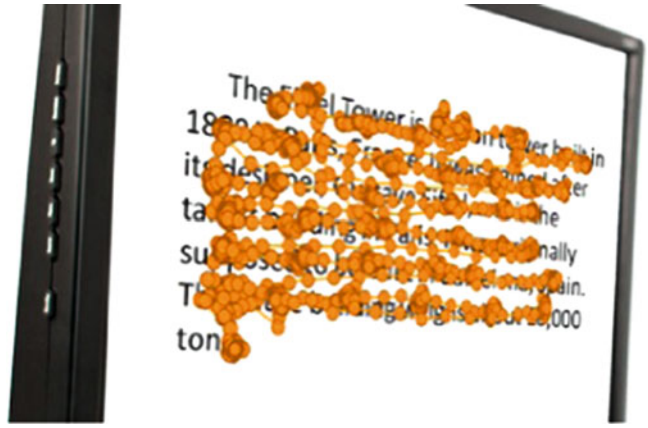

Fig. 1 The fundamentals of eye tracking systems [7]

Fig. 2 An original image of the eye

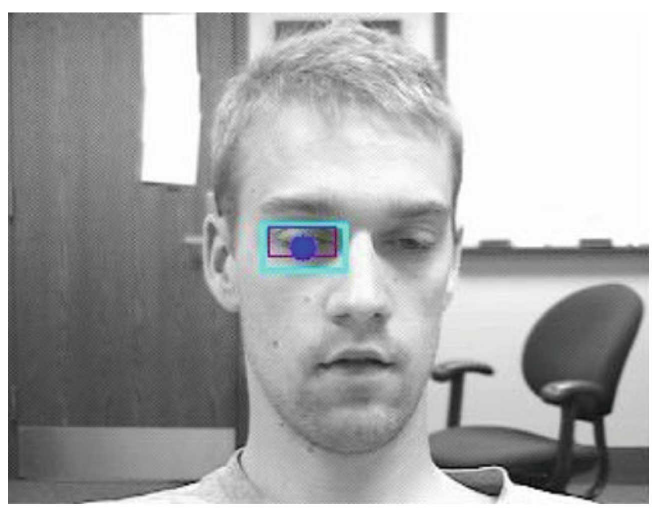

Fig. 3 The correlation between the eye blink and the click of the typical mouse [11]

The Camera Mouse System

The experiences with the camera mouse system can successfully provide computer access for people with severe disabilities. With the eye tracking system, an "eye mouse" is implemented to help people with severe disabilities access computers through eye movements (See Fig. 3). However, the eye feature has not been used effectively with the camera mouse system [12].

For some people with severe disability such as severe cerebral palsy or amyotrophic lateral sclerosis deprives them of the use of their limbs and even facial muscles.

Owing to this kind of extreme disability, many available popular assistive technology systems are not helpful to them [13]. Under this circumstance, an eye tracking system may provide an alternative option for people with severe disabilities who only retain the ability to move their eyes.

There are several different ways to track the directions of eye movements, such as reflection of light and electroo-culographic potential (EOG). Each approach has its own advantages, disadvantages and limitations [3].

An accelerometer- based human-computer interface and a vision based "Head-Mouse" system have been proposed to allow people with disabilities to use their head movements to manipulate computers. Eom et al. suggested a Gyro-Mouse interface that contains two units: hardware and software. The hardware unit consists of the gyroscope sensors measuring the head movements, a module that performs A/D conversion, and a serial transmitter using blue-tooth wireless communication. The software receives the data and converts it to mouse moves and clicks [8].

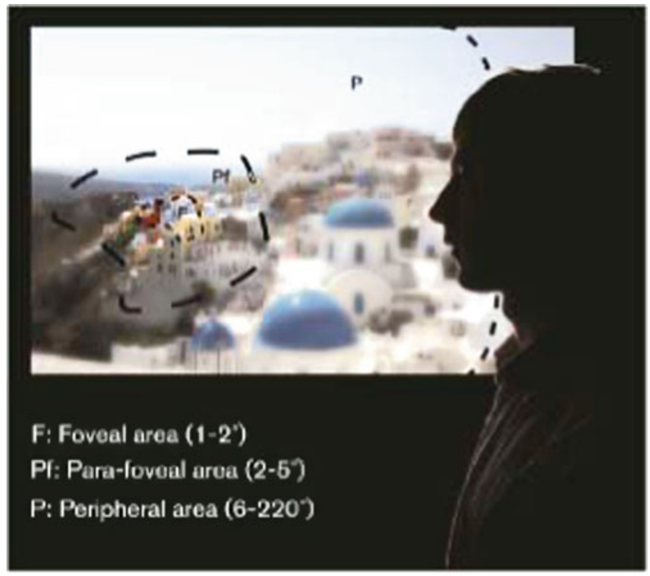

Fig. 4 Visual field of a human eye [15]

Hands-Free Wheelchairs

The development of wheelchairs conventionally uses manual powered wheelchairs and then advances to electrical wheelchairs [14]. Conventional wheelchair relies on manual operation which assumes that users are still able to use their hands and therefore excludes people unable to do so. To allow independent control of the wheelchair by severely disabled users, eye tracking has been investigated as a novel method for controlling the wheelchair. By using right, left up and down eye movements, control commands can be easily sent out. The system uses a camera for capturing eye images. These images are used to track pupil motion by image processing techniques. The color of pupil is darker than other eye parts and the surrounding area. Computations on the binary image of the pupil are performed to determine the central point (m, n) of the pupil u in which Eq. (1) is used [9]:

$$(m,\ n)\ =\ \left(\frac{1}{K}\sum\nolimits_{a=1}^{K} i, \frac{1}{K}\sum\nolimits_{a=1}^{K} j\right) \tag{1}$$

Where (i, j) is a pixel in the image and K is the total number of pixels. The coordinates of the central point of the pupil determines the direction of the gaze.

Head movement is also a natural way of pointing and may be used to replace the joystick of a wheelchair allowing for control. Joseph and Nguyen introduced a prototype of a wheelchair interface that uses triaxial accelerometer to determine the head position and a Neural Network to find the commands given by head movements [10] (Fig. 4).

The Five-Stage Algorithm

A five-stage algorithm is proposed to implement the eye tracking system. At the first stage, an efficient face detection filter based on the skin color information is employed to locate the user's face taken from low-cost web-camera. Then, three projection histograms are integrated to find the eyes [13]. After this, the FCM (fuzzy C-Means) algorithm is employed to locate the pupils. The direction information of eye movements is then computed through inferring simple fuzzy systems. Finally, the computed direction information of eye movements is used to manipulate the computer [16].

Zhu and Ji, have also employed the five-stage algorithm where they also provide hardware specifications of their system [1]. In their case, they have used a 533 MHz Pentium II PC with the Windows 2000 operating system and a web Camera. Comparing to the camera mouse system which involves two computers that are linked together, a SONY EVI-D30 CCD camera with zoom, tilt, and pan mechanisms, a video capture board, and a National Instruments data acquisition board, their system is obviously less costly [6]. The web camera is mounted above the top of the computer monitor. In view of the five-stage algorithm aspect, they have ensured that their camera supplies 30 color images of size 640 × 480 per second. To achieve real-time performance, the five-stage algorithm processes only 177 × 145 pixels at an average frame rate of 30 Hz [13].

The Image-Difference Method

Ebisawa and Satoh on the other hand proposed an image difference method based on two light sources to perform pupil detection under various lighting conditions [6]. The background can be eliminated using the image difference method and the pupils can be easily detected by setting the threshold as low as possible in the difference image [17]. They also proposed an ad-hoc algorithm for eliminating the glares on the glasses, based on thresholding and morphological operations [18].

Results of Past Experiments

Experimental results show that eye tracking can be used to manipulate the computer for people with severe disabilities [16]. This also applies to head movement detection. If the user can use his or her limited voluntary motions in addition to the eye movements, there are many other options for communications and computer access. Otherwise, the eye tracking system is an ideal option because it is a low-cost and non-instructive system [13].

Zhu and Ji seek to provide a clear understanding on how eye trackers can be used. In particular, they focus on integrated eye tracker to track eyes robustly under various illuminations and face orientations [1]. They try it both with many people and with few where it works well. This is inclusive of people with both the pupils directly visible and those otherwise [18]. This has been achieved by combining an appearance based pattern recognition method (SVM) and object tracking (Mean Shift) with a bright-pupil eye tracker based on Kalman filtering [6].

Zhu and Ji focused on the various methods and observe that most methods require bright/dark pupil effect to work well [1]. The success of such system strongly depends on the brightness and size of the pupils which are often affected by several factors including eye closure, eye occlusion due to face rotation, external illumination inferences, and the distances of the subjects to the camera. This is evident in [19]. The use of the differential lightning schemes to generate the bright/dark pupil images, and pupil detection is done after thresholding the difference image. A larger temporal support is used to reduce artifacts caused mostly by head motion, and geometric constraints are used to group the pupils [18].

The Gyro-Mouse system that employs head movement detection in computer interface was presented by Eom et al. The system showed a click recognition rate of 93 % using Neural Network classification. The error in the position of the cursor control was about 1.5 times larger than that of optical mouse [8].

Lin et al. proposed a wheelchair controlled by an optical eye tracking. The speed and direction of the wheelchair depends on the duration and the direction at which the user gazes. When the eye gazes in a specific direction, the input command increases in that direction until it reaches the increment value set and the movement will occur according to that value [9]. Although such a system is not easy to control and requires the ability to control the eye and the suitability of the user's head position, research is still on-going to provide the handicapped with independent mobility and the results are promising.

Conclusion

In conclusion, eye tracking and head movement detection have come as blessings not only to the disabled but to the wider society. It is an area that has allowed the disabled to be involved in the economic activities of the world especially in the digital era. Experiments have shown that, the identified enhancements have brought tremendous effects and actual improvements in both fields of eye tracking and head movement detection. Robustness and accuracy over existing methods continues to increase with more research being done.

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A Comparative Study of Simulation Based Performance Evaluation of Routing Protocol for Ad-Hoc Networks

Ola Alsaqour, Raed Alsaqour, Tariq Alahdal, Rashid Saeed, and Mohammed Al-Hubaishi

Abstract

This study introduces comparison of two simulation-based performance evaluation papers, the first paper called “A Performance Comparison of Multi-Hop Wireless Ad Hoc Network Routing Protocols” and the second one called “Simulation-based Performance Evaluation of Routing Protocols for Mobile Ad Hoc Networks”. This paper criticizes the choices selection for each simulation. These two papers present a performance evaluation of four typical routing protocols of ad-hoc networks which are DSDV, TORA, DSR, and AODV using the simulation technique. As the performance of an ad-hoc network protocol can vary significantly with different mobility model the first and the second paper chooses a different mobility model “Waypoint” and “Gauss-Markov” model, respectively. This leads to a different behavior of each model results. The first paper found out to be more systematic, realistic, and its performance evaluation has a better level of details including the MAC and link layer details in the simulation rather than the second paper which is more superior mainly in choosing “Gauss-Markov” mobility model. Furthermore, it found out the first paper’s “end-to-end delay” metric is more proper choice over the second paper’s “path optimality” metric since it depends on the algorithm more than the load.

Keywords

MANET • DSDV • TORA • DSR • AODV • Routing • Simulation

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Introduction

A mobile ad hoc network (MANET) is a collection of wireless mobile nodes communicating with each other using multi-hop wireless links without any existing network infrastructure or centralized administration [1]. If two hosts are not within the radio coverage of each other, messages must be passed through the intermediate hosts which double as a router to discover “multi-hop” paths through the network to any other node. Figure 1 shows an example of such a multi-hop MANET with four nodes. In Fig. 1, the circle around each node represents its radio range. Node S has one neighbouring node, node number 1, within its radio range, but the destination D is beyond its radio range. Thus, to communicate with D, S must use a multi-hop path S12D.

In recent years, a variety of routing protocols targeted specifically at this environment have been developed due to the free movements of the nodes. Thus routing protocols

T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_29,

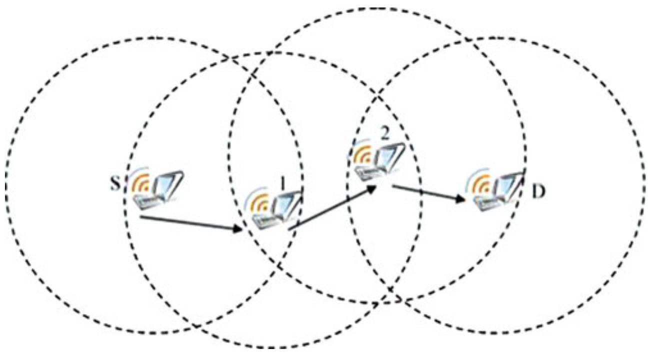

Fig. 1 MANET

must be adaptive and able to maintain routes in spite of changing topology and network connectivity.

Networks using ad-hoc configuration concept can be used in many military and emergency contexts where cellular infrastructure is unavailable or unreliable, also in commercial application such as on-the-fly conferencing application [2, 3].

In an interest to run internetworking protocols of MANET, a working group for MANET has been established within the Internet Engineering Task Force (IETF) [4] to standardize IP routing protocol functionality suitable for wireless routing application within Ad-hoc configuration.

Performance of MANET routing protocols is one of the key criterions of the design and deployment of such networks and any change in the performance evaluation assumptions or techniques impacts significantly the output results of the whole study. One key problem to Wireless MANETs is foreseeing the variety of possible situations that can occur. So modeling and simulation using extensive parameter sweeping and what-if analysis becomes an extremely important paradigm for use in ad hoc networks.

The main goal of this paper is to carry out a systematic study and a comparison of two papers. The first paper called "A Performance Comparison of Multi-Hop Wireless Ad Hoc Network Routing Protocols" [5] and the second one called "Simulation-based Performance Evaluation of Routing Protocols for Mobile Ad Hoc Networks" [4]. These two papers present a performance evaluation of four typical routing protocols of MANETs which are DSDV, TORA, DSR, and AODV using different simulation models, methodologies and some different metrics. Different routing protocols are suitable for different network characteristics. In other words, this paper shows a comparative study for these two papers for the different simulation model including the communication models, mobility models, the workload selection and metrics draws a complete and valuable conclusion.

Generally, routing protocols are classified into two main categories: Table-driven routing protocols and source initiated on-demand driven routing protocols. The table driven routing protocols maintain consistent and up-to-date routing information from each node to the rest of the nodes in the network in one or more routing tables regardless of the need of such routes. The source initiated on-demand routing protocols are developed and employed in mobile ad-hoc networks and initiates routing activities only when needed.

In another classification, these protocols generally fall into one of two categories: proactive or reactive. Proactive routing attempts to maintain optimal routes to all destinations at all times, regardless of whether they are needed. To support this, the routing protocol propagates information updates about a network's topology throughout the network. In contrast, reactive or on-demand routing protocols determine routes to given destinations only when there is data to send to those destinations. If a route is unknown, the source node initiates a search to find one. Proactive routing protocols have the advantage of having short routes available at all times, thereby avoiding the delay of searching for a route on demand. Reactive routing protocols have the advantage of only generating routing overhead to find routes when routes are needed, independent of network topology changes.

The rest of the paper is organized as follow. In section "MANET Routing Protocols", a brief description of the studied protocols is given. Section "Simulation Environment" discusses the simulation environment, performance metrics and other simulation settings used in evaluation by the two papers. The results summary and the conclusion are presented in sections "Simulation Results Comparison" and "Conclusion" , respectively.

MANET Routing Protocols

Destination Sequenced Distance Vector: DSDV

DSDV is a hop-by-hop, proactive distance vector routing protocol [6]. In DSDV, each network node maintains a routing table that contains the next-hop and number of hops to all reachable destinations. The nodes periodical broadcast of routing updates attempt to keep the routing table completely updated at all times.

To guarantee loop-freedom routing [7], DSDV uses a concept of sequence numbers to indicate the freshness of a route. A route *R* is considered more favorable than *R*' if *R* has a greater sequence number or, if the routes have the same sequence number, *R* has lower hop-count. The sequence number for a route is set by the destination node and increased by one for every new originating route advertisement. When a node along a path detects a broken route to a destination *D*, it vertices its route to *D* with an infinite hop-count and a sequence number increased by one.

Route loops can occur when incorrect routing information is present in the network after a change in the network topology, e.g., a broken link [8]. In this context, the use of sequence number adapts DSDV to a dynamic MANET network topology.

DSDV uses triggered route updates when the topology changes. The transmission of updates is delayed to introduce a damping effect when the topology is changing rapidly. This gives an additional adaptation of DSDV to Ad-Hoc networks.

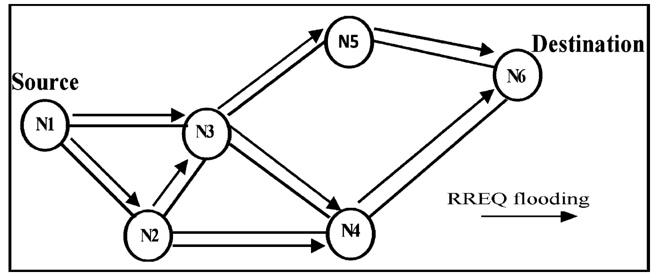

Fig. 2 Propagation of RREQ Packet in AODV

Ad-hoc On Demand Distance Vector: AODV

The AODV is a reactive distance vector routing protocol [9]. AODV requests a route only when needed and does not require nodes to maintain routes to destinations that are not communicating. The process of finding routes is referred to as the route acquisition henceforth. AODV uses sequence numbers in a way similar to DSDV to avoid routing loops and to indicate the freshness of a route.

Whenever a node needs to find a route to another node it broadcasts a Route Request (RREQ) message to all its neighbors [10]. As shown in Fig. 2, the RREQ message is flooded through the network until it reaches the destination or a node with a fresh route to the destination. On its way through the network, the RREQ message initiates creation of temporary route table entries for the reverse route in the nodes it passes. If the destination, or a route to it, is found, the route is made available by unicasting a Route Reply (RREP) message back to the source along the temporary reverse path of the received RREQ message as shown in Fig. 3.

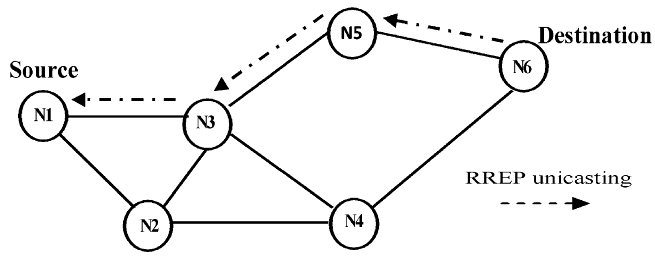

Fig. 3 Path of RREP Packet in AODV

On its way back to the source, the RREP message initiates creation of routing table entries for the destination in intermediate nodes. Routing table entries expire after a certain time-out period [10].

Neighbors are detected by periodic HELLO messages. If a node x does not receive HELLO messages from a neighbor y through which it sends traffic, that link is deemed broken and a link failure indication (a triggered RREP message) is sent to its active neighbors [8, 11]. When the link failure messages eventually reach the affected sources, the sources can choose either stop sending data or requesting a new route by sending out new RREQ messages.

Dynamic Source Routing: DSR

DSR routing protocol uses a technique where the source of a data packet determines the complete sequence of nodes' route through which to forward the packet [12]. The source explicitly lists this route in the packet's header. DSR builds routes on demand (reactive) using flooded query packets that carry the sequence of hops they passed through.

Once a query reaches the destination, the destination replies with a reply packet that simply copies the route from the query packet and traverses it backwards. Each node has route cache, where complete routes to desired destinations are stored as gleaned from the reply packets. These routes are used by data packets. Route failure is detected by the failure of an attempted message transmission. Such a failure initiates an error packet sent backward to the source. The error packet erases all routes in the route caches of all intermediate nodes on its path, if the route contains the failed link [13].

Temporally-Ordered Routing Algorithm: TORA

The unique feature of the TORA routing protocol is the maintenance of multiple routes to the destination so that many topological changes do not require any reaction at all, as having just a single route is sufficient. The protocol reacts only when all routes to the destination are lost. In that case, routes are reestablished via a temporally ordered sequence of diffusing computations, which are essentially link reversals. In the event of network partitions, the protocol is able to detect the partition and erase all invalid routes [13].

Simulation Environment

As the simulation model allows the alternatives setting to be compared under a wider variety of workloads and environments, choosing the proper modeling and environment setting can be challenging and can affect drastically the performance evaluation process leading to a various output results. The two papers have chosen some different criterias and assumptions through their simulation studies which are described and criticized momentarily in this paper.

A discrete event, packet level, routing simulators were used by the two papers, the first paper used Network Simulator version 2 (NS2) which was developed by the university of California at Berkeley and the VINT project [14] while the second paper used MaRS (MaryLand Routing Simulator) [15]. As these two simulators were insufficient for modeling MANETs, many modifications and extends were made to provide accurate simulation of mobile wireless networks.

Simulation Parameters

In the two papers, each node has a fixed radio range, for each node out of the range the link cost is set infinity, while in the second paper the link cost is modeled using hop-normalized delay also each node is modeled by a store and-forward and a queue for packets awaiting transmission by the network interface. In the first paper the node is characterized by the antenna gain, transmit power, and receiver sensitivity but the second paper characterized the node according to the buffer space and processing speed. In both papers the link was characterized by bandwidth and propagation delay.

The second paper was limited to network layer details, thus no link layer details, such as the multiple access interference, the Medium Access Control (MAC) protocol or link errors are modeled, nor are any physical, radio channel level details. Since this is the adopted assumption each link owns, the entire channel bandwidth in transmitting packets which can be a broadcast or unicast packets (data packet are always unicast meanwhile routing packets can be broadcast or unicast depending on the protocol requirements).

This actually made the second paper less representative and mimic to the real procedure and this makes the first paper more realistic because it take into consideration many details related to the physical, data link layer and radio propagation model to determine the power level of the received signal at each mobile node and according to the determined signal power value the state of the packet is justified. Also, the link layer in first paper simulation implements the complete IEEE 802.11 stander MAC protocol Distribution Coordination Function (DCF) which designed to reduce probability of collisions due to the hidden terminals using Request-to-Send/Clear-to-Send exchange that reserve the wireless channel for transmission of a data packet and each correctly received unicast packet is followed by an acknowledgment to the sender, which retransmits the packet a limit number of time until this ACK packet is received.

Routing packets which are used for routes maintenance are distinct from data packets in both papers' simulations and have a higher priority over data packets in node's outgoing packet queue. Data packet processing time is fixed while the routing packet processing time and size depends on the routing protocol being used, such as for source routing the header length is variable depending on the route length. This distinction and priority makes monitoring and tracing the impact for such packets is much easier.

Detecting a link failures or reappearance in one of the key feature of mobile network which can be done by what is so-called hello messages or acknowledgments on the link layer level, and these two features can be taken as discrete events for both simulations but these are not modeled in the second paper and since the link layer details is ignored. So the discrete event is generated automatically whenever a link fails or reappears meanwhile the first paper mechanism in generating discrete event is more appropriate since they are included in a group of pre-generated scenario files which are driven in a close manner to the real changes in the network links.

Mobility Model

In the performance evaluation of a protocol for MANET, the protocol should be tested under a realistic conditions and movements behavior of the mobile users (i.e. a mobility model) [16]. A mobility model should attempts to mimic the movement of real mobile nodes, changes in speed and direction must occur but in a reasonable time slots. Because the choice of mobility model which the researchers adopt can affect drastically the performance results obtained especially in the performance of MANET routing protocols which are very sensitive to movement patterns.

There are two types of mobility models used in simulation of networks: traces and synthetic model [16]. The later is adopted by the two papers and it attempts to realistically represent the behaviors of the mobile nodes (MN) without the use of traces. The first paper used a synthetic model called "Random Waypoint" [16]. In Random Waypoint, the movement scenario files used for each simulation are characterized by pause time. As shown in Fig. 4, in this mobility model, MN moves from its current location to a

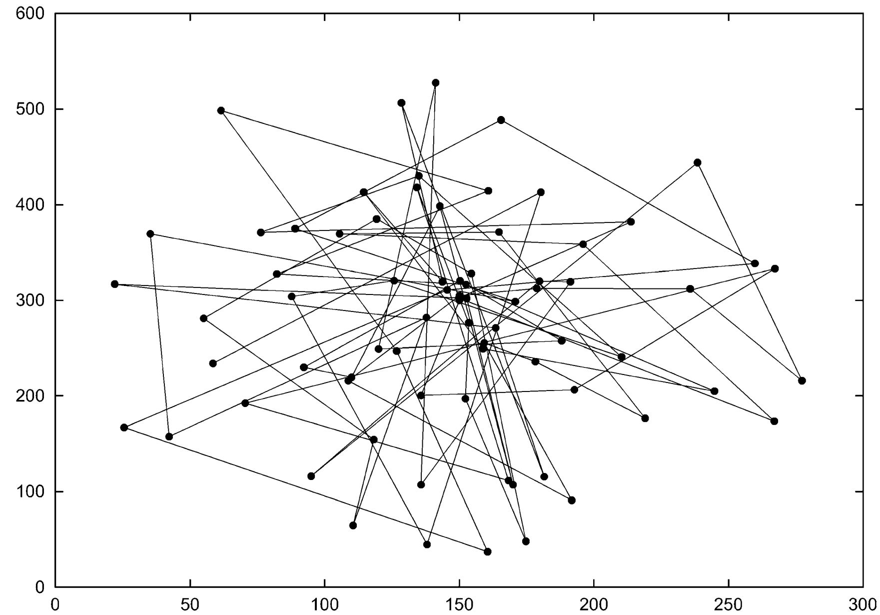

Fig. 4 Random Waypoint mobility model

new one in a random choosing for moving speed and direction which are both chosen from predefined ranges [Speedmin, Speedmax] and [0,2π], respectively. But any changes in the direction or speed from location to another happen after a certain period of time called "pause time". Once the time is expires, the MN is free to choose a new random path. This model is memory less mobility model because it retains no knowledge concerning its previous location and the speed values.

The parameters' details of the simulation setting was a choice of 50 wireless nodes forming MANET, moving over a rectangular flat space (1,500 m × 300 m) for 900 s of simulation time. Two hundred and ten different scenario files were pre-generated and each file describes the exact motion of each and sequence packets originated for each node. Moreover, the exact time at which each change in motion or packet origination is to occur. Each run of the simulation accepts one of these scenario files as an input.

For the second paper, the nodes move using Gauss-Markov mobility model [16]. Gauss-Markov mobility model is more realistic model than the one chosen in the first paper and this put more stress on the routing protocols. In this model, the node movements are discretized for ease modeling and each node chooses a direction, speed and distance of move based on a predefined distribution and then computes its next position and direction with respect to the direction of the previous move, considering the pervious direction to computes the current direction.

Figure 5 illustrates an example traveling pattern of an MN using the Gauss-Markov mobility model. As shown in Fig. 5, the Gauss-Markov mobility model can eliminate the sudden stops and sharp turns encountered in the Random Walk mobility model by allowing past velocities (and directions) to influence future velocities (and directions).

In considering the previous direction to compute the current direction, this is actually one of the mobility choices that makes the second more superior, because this eliminates the sudden stops and sharp turn that happens in the random waypoint model. The simulation setting details in the second paper is a 30–50 nodes moving in region size 1,000 m × 1,000 m, the speed of each node is uniformly distributed between a given range (0.4–0.6 m/s for low mobility experiments and 3.5–4.5 m/s for high mobility experiments). Distance is exponentially distributed with a mean of 5 m and the direction is uniformly distributed within [−π/8, +π/8] with respect to the direction of the previous move. All simulations are run for 10,000 simulation seconds.

The second paper also a superior in choosing a long simulation time 10,000 s which is more proper than 900 s in the first paper because the MN in both papers are initially distributed randomly around the simulation area. This initial random distribution of MNs is not representative of the manner in which nodes distributed themselves when moving. Some studies in this field show a high variability in the average MN percentage (cumulative percentage of total MNs that are a given MN's neighbor) during the first 600 s of simulation time. This high variability in average MN neighbor percentage produces high variability in performance result unless the simulation results are calculated from long simulation run [16]. For the simulation chosen area shape, the first paper chose a more proper area shape which is a rectangular space in order to force the use of longer routes between nodes than would occur in a square space with equal node density.

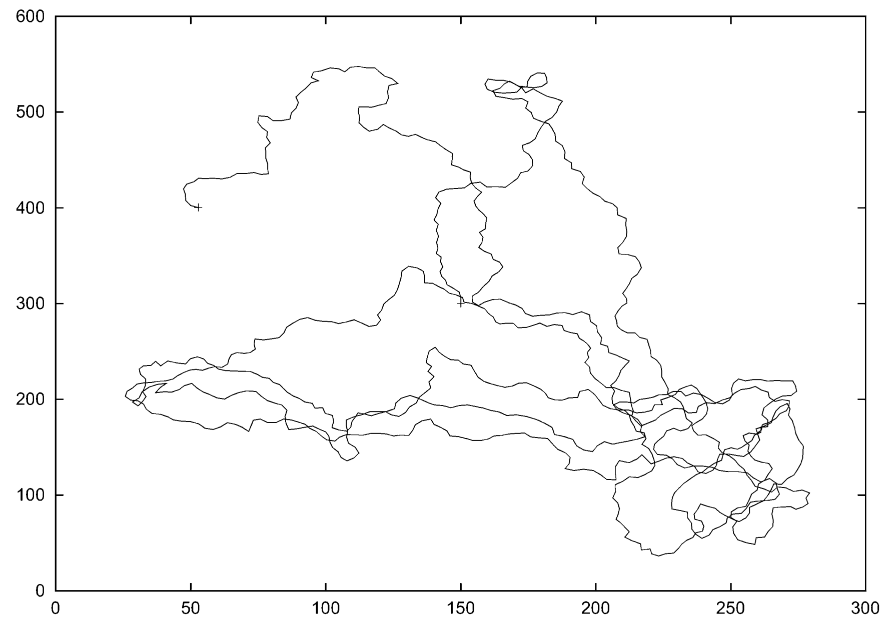

Fig. 5 Gauss-Markov mobility model

Performance Metrics

In comparing MANET protocols, the first paper chose to evaluate them according to the following three performance metrics:

- Packet delivery ratio: The ratio between the number of packets originated by the "application layer" CBR sources and the number of packets received by the CBR sink at the find destination.
- Routing overhead: The total number of routing packets transmitted during the simulation. For packets sent over multiple hops, each transmission of the packet (each hop) counts as one transmission.
- Path optimality: The difference between the number of hops a packet took to reach its destination and the length of the shortest path that physically existed through the network when the packet was originated.

The second paper uses the same metrics except using extra end-to-end delay metric which is the delay includes processing and queuing delays in each intermediate node, instead of the third one above.

The first two choices of metrics are robust as the packet delivery ratio is important to measure the loss rate in the network which in turn affects the maximum throughput of the network. While the routing overhead metric has an importance for measuring the scalability of the protocol and the degree to which it will function in congested or low-bandwidth environments, but even though this metric precisely does not fit with the second paper's assumption as it ignores the congestion and interference situations.

For the end-to-end delay metric, it is a proper metric more than the path optimality which it depends primarily on the algorithm rather than the load, but for the delay metric which is affected by the mobility and the data rate because high data rate will fill up the buffers very quickly. The low mobility means that already found routes are valid for a much longer time period. This means that found routes can be used for more packets. Even the packets that have stayed in the buffer for a long time have a chance to get through. When mobility increases, more routes become invalid and new requests are necessary. While the requests are propagating the network in search for a new route, buffers will get full and packets are dropped [17].

Simulation Results Comparison

The first paper's simulation results show that each of the protocols studied performs well in some cases yet has certain drawbacks in others. DSDV performs quite predictably, delivering virtually all data packets when node mobility rate and movement speed are low, and failing to converge as node mobility increases. TORA, although the worst performance in their experiments in terms of routing packet overhead still delivered over 90 % of the packets in scenarios with 10 or 20 sources. At 30 sources, the network was unable to handle of the traffic generated by the routing protocol and a significant fraction of data packets were dropped. The performance of DSR was tremendous at all mobility rates and movement speeds, although its use of source routing increases the number of routing overhead bytes required by the protocol. Finally, AODV performs almost the same as DSR at all mobility rates and movement speeds and accomplishing its goal of eliminating source routing overhead but it still requires the transmission of many routing overhead packets and at high rates of node mobility is actually more expensive than DSR.

While results of the second paper show that the proactive, shortest path protocols provide outstanding performance in terms of end-to-end delays and packet delivery fraction at the cost of higher routing load. The on-demand protocols suffer from suboptimal routes as well as worse packet delivery fraction because of more dropped data packets. However, they are significantly more efficient in terms of the routing load.

The multipath protocol, TORA, did not perform well in spite of maintaining multiple redundant paths. Also, the end-to-end delay performance is poor because of the loss of distance information. However, the other performance differentials are not affected conclusively. Rate of mobility and network size do not seem to affect the performance beyond what is normally expected—such as higher routing load, more delay and dropped packets.

Conclusion

The performance of MANETs routing protocols can vary significantly with different mobility models. The first and the second paper choose a different mobility model "Way-point" and "Gauss-Markov" model, respectively. This leads to a different behavior of each model. Moreover, the first paper is more systematic in its performance evaluation and presenting the simulations steps, it also has a more realistic simulation model by including more level of details regarding to the link layer implementation than the second paper. also makes a workload tuning and validation, in addition to that the first paper "end-to-end delay" metric is more proper choice over the second paper "path optimality" metric since it depends on the algorithm more than the load.

The reason behind the second paper' weight is the mobility model choice which can mimic the real mobility of the ad-hoc nodes and also the second paper is more credible by showing the limitation of its study which can help more in the future work.

Acknowledgment This research was supported in part by the Centre for Research and Instrumentation Management (CRIM), University Kebangsaan Malaysia (UKM), Malaysia. Grant: UKM-GUP-2012-089.

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Vulnerability Studies of E2E Voting Systems

Lauretha Rura, Biju Issac, and Manas Haldar

Abstract

In the recent years, the existence of end-to-end voter-verifiable (E2E) voting system had increased significantly. Some of the prospective ones have been used in a medium to large scale elections. We have also developed one (eVote). In this paper we review their capabilities to provide an individual and universally verifiable voting system, incoercibility and receipt-freeness to ensure election integrity. We compare some properties along with its resistance against malicious attacks.

Keywords

End-to-end verifiable system • Electronic voting • Attacks • Security threats • System requirements

Introduction

Electoral elections are mostly done in conventional way by manually submitting paper ballots to centralized ballot box allocated in few different precincts. However, in modern day the election processes are often carried out by the electronic voting system. It is a set of mechanisms that enable the process to go through the entire necessary path to reach the ultimate goal [1]. In electronic voting system, there is one aspect that is very crucial and important for the system to earn, which is trust. Voter's trust could be build up by upholding an election that supports full integrity and secrecy. This means the electronic voting system must allow the voters to actually verify the accuracy of their votes, whether the vote that they have casted has been casted, collected and counted properly or not. Researchers have been developing and implementing many schemes in order to support this. One of the technologies developed is E2E verifiable voting system.

In principle, E2E voting system offer assurance to the voters as they cast their vote by distributing a receipt of their vote which can be used for verification purpose from the overall tabulation of the collected votes. Yet on the other hand, this receipt cannot be used as a proof in vote buying or vote coercion although all of the receipts will be posted publicly in a read-only Bulletin Board once the voter finished the voting process. Therefore, the E2E system supports incoercibility yet still protects the voter's privacy. This scheme allows the voters to trust its election procedure a level ahead of the other conventional paper-based election or any other standard electronic voting systems. There are two main categories of E2E system based on its physical ballot, paper-based E2E voting system and electronic E2E voting system. For paper-based E2E voting system, vote verification is to be completed by using part of the physical ballot which has been given to the voter after they completed the registration and authentication stage as a receipt from the vote casting process. On the other hand, voters would cast their ballot electronically in electronic E2E voting system. Therefore, they would not obtain a physical ballot to cast their votes, instead they will be given a unique confirmation or verification code to

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_30,

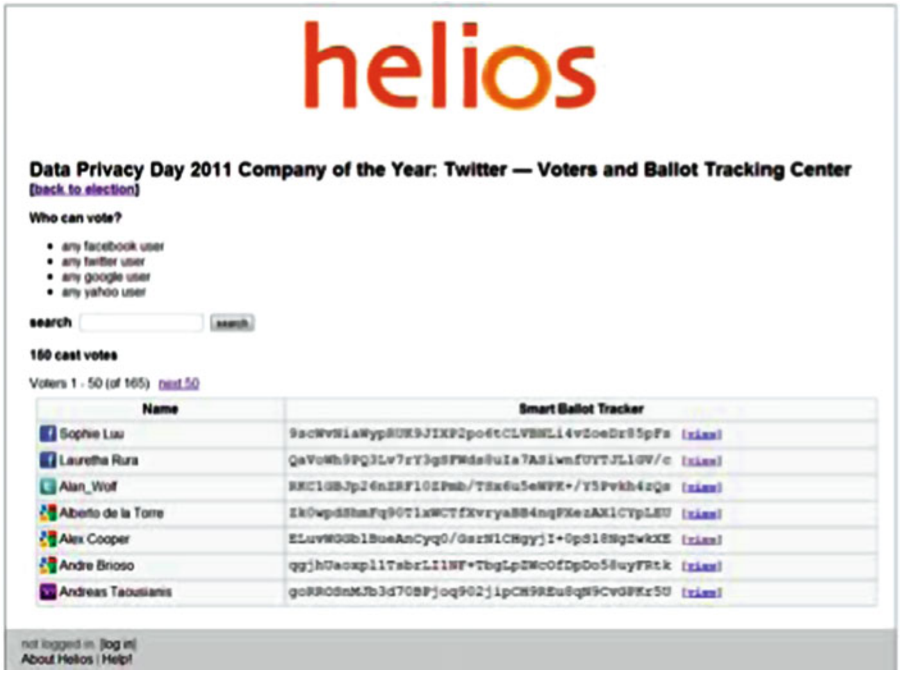

Fig. 1 Voters and Ballot tracking center of Helios voting system

verify the credibility and accuracy of their vote against the list displayed on the bulletin board.

In section "Related E2E Voting Systems" some E2E voting systems which have been applied in the range of medium to large scale elections are discussed in more details. These systems include Helios web-based open-audit voting system [2], Scantegrity II [3], Prêt à Voter system [4] and Rijnland Internet Election System [5]. Section "Proposed E2E Voting System" covers our proposed E2E voting system, followed by the general E2E voting system requirements along with the common threats of electronic voting systems in section "E2E System Requirements and Threats". These measurements are to be used against those E2E systems described before to ensure its capability. In section "Comparison and Results", the E2E systems described in section "Related E2E Voting Systems" together with the proposed voting system would be compared to indicate its competency. Finally, this paper is concluded in section "Conclusions" along with some ideas for the future works of E2E voting system.

Related E2E Voting Systems

Helios

Helios Voting System is a system developed based on Benaloh's Simple Verifiable voting protocol [2] as well as Sako and Killian's mix-net scheme. This open-source web-based open-audit voting system that offers verifiable online elections for anyone was created by Ben Adida [2]. It was designed to cater and to ensure a clean setting of election where coercion is not the main concern (low-coercion elections are tolerable to be carried out with Helios) but ballot secrecy and election integrity are still applicable through its open-audit election. Both of these aspects cannot be achieved in a typical traditional election where only elections officials are entitled to do the observation throughout the election process.

Its procedure for voters in general is separated into two main stages, ballot preparation and ballot casting. Both of the stages cannot be compromised in order to achieve an end-to-end verifiability that consists of not only the correct ballot preparation or recording process but also a secure tally procedure. To ensure this, Helios implements smart ballot tracker; a feature of ballot verification called Ballot Tracking Center (Bulletin Board) as shown in Figs. 1 and 2 where each user could verify that their votes has been received and tallied correctly. Voters' authentication is carried out during ballot casting phase at the end of the election process to offer individual and universal verifiability to anyone whom wishes to validate Helios' ballot preparation mechanism despite of their eligibility to access the system.

The current improved version with a number of practical features to enhance its efficiency and security which is version v.3.1 is accessible on http://heliosvoting.org. It offers a better and more solid approach to protect system's privacy by appointing multiple trustees instead of one Helios server as the main trustee. Each one of these trustees is to decrypt the final tally of the election and not individual

Fig. 2 Example of Helios smart ballot tracker

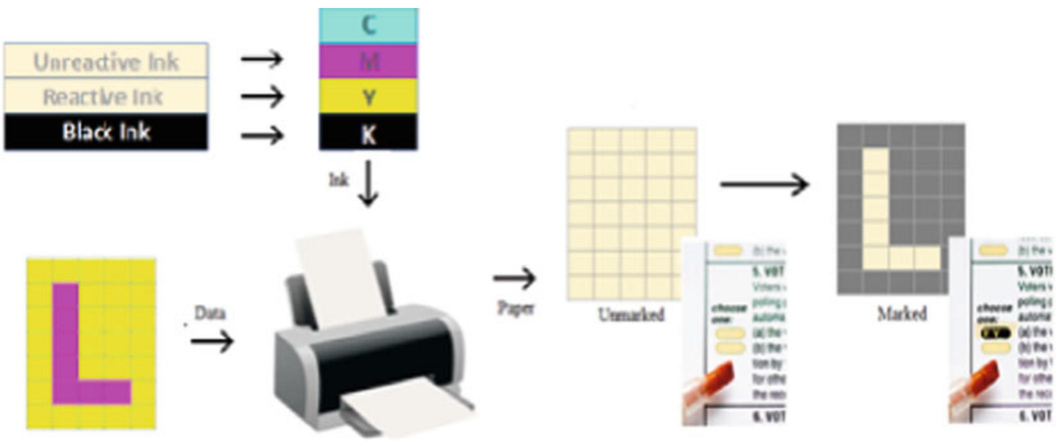

Fig. 3 Process of invisible ink printing [6]

ballot by using advance cryptographic techniques. This way, the possibility of potential privacy to be compromised could be averted.

Scantegrity II

Helios Scantegrity II is a practical enhancement for optical scan voting systems that achieves increased election integrity through a novel use of confirmation codes printed on ballots in invisible inks [3]. Punchscan and Scantegrity were its predecessors. The three electronic voting systems make use of optical scan technology in their system. Punchscan was designed with anonymity network often referred to as the Punchboard. It joins binding commitments table and Randomized Partial Checking (RPC) [6] to permute the votes in order to hide the link between voters and their cast vote. The same approach was used for Scantegrity. The mechanisms of these systems are similar to one another. They are emphasizing on voting verifiability by using optical scan devices with similar paper ballots. However, Scantegrity prevents some of the issues raised by the other two systems, Punchscan and Scantegrity. One of them is randomization attacks which can be tackled by Scantegrity II with its Invisible Ink mechanism. It is an attack that resulted in the nullification of the voters' choice by forcing the voters to randomly cast irregular votes that appear to be the same as the balloting materials to the system [7]. This technology allows the voter to retain their receipt in a secure and secret that no attackers would be able to coerce their votes. Receipts on voters' ballot are to be kept secret and will only be visible to the voters as they casted their votes. No information regarding the confirmation codes would be accessible to anyone before the votes are casted. Due to that particular reason, Scantegrity II could earn more trust and confident by the voters as illustrated in Fig. 3.

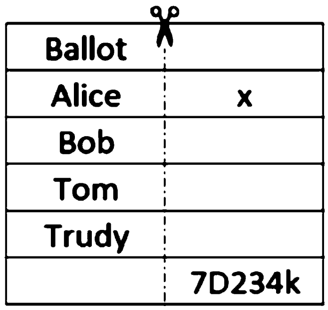

Fig. 4 Prêt à Voter's sample ballot

Prêt à Voter (PV)

Helios This system introduces another new approach of vote encoding. Users' votes are encoded in randomized candidate list. There are four stages in its system design, such as: ballot generation, vote capture, vote processing and auditing [4]. In generating their ballot, PV uses detachable paper ballot of candidate list in random order which will be destroyed to ensure users' privacy and the corresponding boxes where the users can indicate their vote(s) [8]. The other part of the ballot will be kept by the users for verification purpose. In both parts of the paper ballot there is encrypted information named 'onion'. It is applied to reconstruct the shuffled candidate list for each ballot in the proper order as the other part of the ballot is scanned (cast) after the vote capture stage. To ensure all of the votes have been shuffled correctly and thus the connection between voters and their votes are detached (votes anonymity), PV implements mix-net decryption scheme. A set of collected ballots would be passed around few authorized mix-servers to shuffle and decrypt the ballots [9]. Once the decryption process is done and the ordered candidate list together with the user's vote have been retrieved, the vote can then be tallied (Fig. 4).

RIES

This voting system is a multiple technology election system which was applied for the first time in 2004 Water Boards Election at Rijnland and De Dommel [5]. It allows eligible voters to cast their votes in two distinct techniques; either by mail or they can also cast it electronically. Similar to other E2E voting system, RIES was developed in order to increase the actual number of voters who cast their votes as well as to decrease unnecessary cost of the conventional election via mail [5]. It provides internet voting scheme in such simple, straight forward and transparent way without overlooking the system's reliability together with its performance and maintenance cost.

The main administrator in this election is called TTPI. It stands for Trusted Third Party Internetstemmen which was formed by RIES's designer and developer. TTPI holds a very important role in the election itself and has more or less the same job scope as election officials. The election procedure of RIES is divided into three parts; they are the initial stage, the election stage and the tally stage. During the initial stage, TTPI would generate a pre-election reference table which contains every possible vote for every voter in MD5 key-less hashes value (MDC). As voters submit their ballots in the election stage, the system would calculate hash value by using each voter's personal secret key (MAC) and construct post-election table. Individual and universal verifiable are offered by this system through checking each of the vote validity. It can be determined by computing MDC of all the casted votes in the post-election table and checking it against the hashes value in the pre-election table [5].

Proposed E2E Voting System

In this paper we propose a voting system based on the same design concept as E2E voting system itself. We call the online voting system as *eVote system*. It differs from the previous work done by other researchers as it emphasizes on two distinct schemes. They are cryptography and steganography. Both branches of information security are combined together in this research to ensure the design of a secure electronic voting system by providing a double layer of data protection. In electronic voting, cryptography is a commonly used technique as it is a good defense against threats. It is used to protect the data transmitted between the voter and the server to ensure that it would not be leaked to a third party. In this proposed system it has been narrowed down to only a few selected schemes. Each of them would be applied in different voting stages to preserve the main characteristics of an electronic voting system. Those schemes are secret-ballot receipts theory, visual cryptography and threshold decryption cryptosystem. Secret-ballot receipts is mainly a combination of cut and choose scheme together with visual cryptography.

On the other hand, steganography has rarely been used as an additional layer of security in electronic voting system and it can offer a better solution for the threats and risks that might occur. Steganography—a branch of information security technique that has not been commonly used in this field is also included in the software architecture design. It is science of hiding information in communications, where apart from the sender and receiver, others would not know the existence of hidden information [9]. Steganography can be better used than cryptography based on its ability to offer less suspicious way of hiding a secret. Therefore, steganography is proposed to be used to secure the data communication in this research, as its purpose is to maintain a secret communication between two parties. The

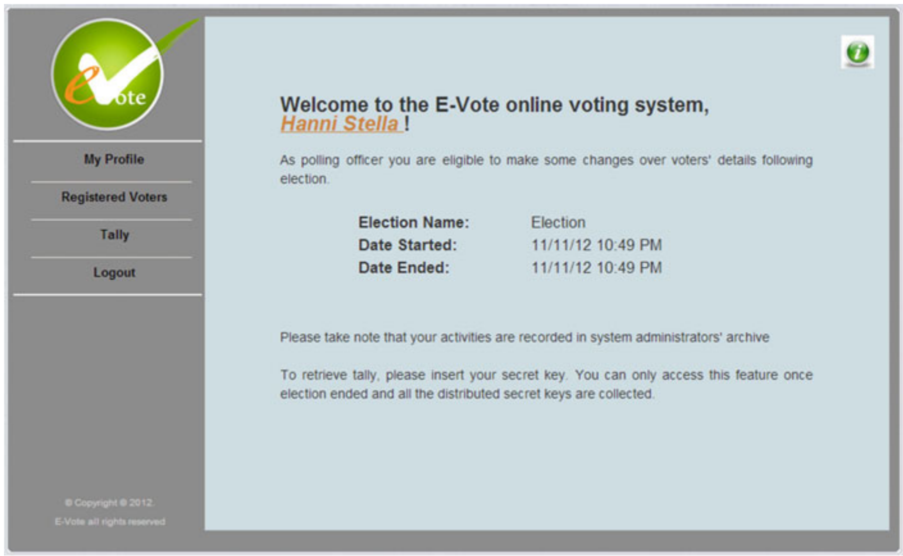

Fig. 5 Homepage of eVote voting system (officer's level)

combination of these two schemes are expected to produce an improved technique which could meet the voter's demand as well as perform with less computational cost in a secure manner.

For electronic voting system implementation, both image and text steganography are the appropriate candidate. They have a higher degree of redundancy, which allow larger size data to be encoded into the cover file. Other than that, they also would not be more likely to raise any suspicion because they are the most common transmitted data between the voter and the server. However, image steganography on the other hand, offers a better encoding technique to be used as it can securely hide the secret message by securely transferring a hidden secret in a digital image file. Ergo, the implementation of image steganography is proposed in this research project.

There are five different stages in the system design architecture such as—registration stage, authentication stage, voting stage, tallying stage, publishing and verification stage. Besides that, there are three types of users in this proposed scheme. They are system administrators, polling officers and lastly the voters themselves. Polling officers' role is applied here due to the proposed system's nature. We suggest a system that is flexible to be implemented and utilized. Voters could choose where to cast their vote based on their own preference. It could be done independently with their own PC as long as it is connected to the server PC as well as in the polling booth with polling officer's help by using the provided PC. Secret-ballot receipt scheme is going to be applied in the voting stage together with visual cryptography as a technique to preserve the secrecy of the ballot receipt in order to enable incoercibility as well as to support verifiability. Each voter is to be given a receipt for verification purpose after they have casted their vote. However, this receipt would not reveal any information of their casted ballot to anyone but the voter who holds the receipt itself as it has been encrypted by using visual cryptography. Steganography would be used throughout the system processes for data communication purpose. In the tallying stage, the threshold decryption cryptosystem will be implemented. Secret keys are to be distributed to different polling officers. Once the election is ended then only the system administrator could distribute the key for those appointed officers to unlock the 'ballot box'. Tally would then be retrieved after all those officers have submitted their own secret keys and 'ballot box' is accessible. No one, not even the system administrator could access the bulletin board before the 'ballot box' is opened. The combined method is believed to be sufficient to provide a secure, reliable and convenient voting system. Since the proposed tool is an electronic voting system, it is necessary to assume that the voter would complete the voting process secretly (Figs. 5, 6, and 7).

E2E System Requirements and Threats

E2E voting systems emphasize their uniqueness in its verifiability feature. This is the main components of such voting system, to construct a transparent election that guarantees its integrity and preserves ballot secrecy in an appropriate period of time. The completion time needed to carry out major tasks of electronic voting system should not be longer compare to the conventional paper-based voting systems. To ascertain a voting system's security, reliability and efficiency while providing proper system's usability, there are various numbers of voting systems' principles and standards that need to be accomplished. It ranged from

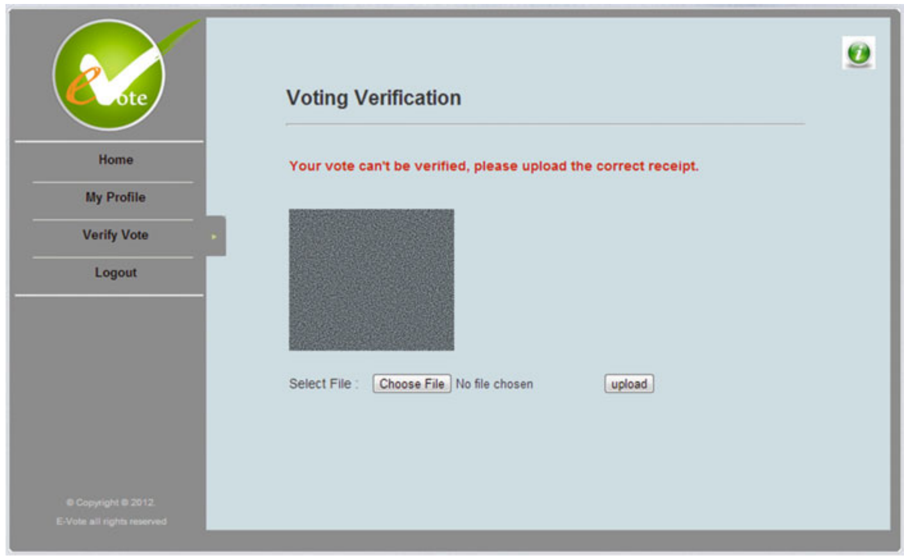

Fig. 6 eVote system voting verification feature

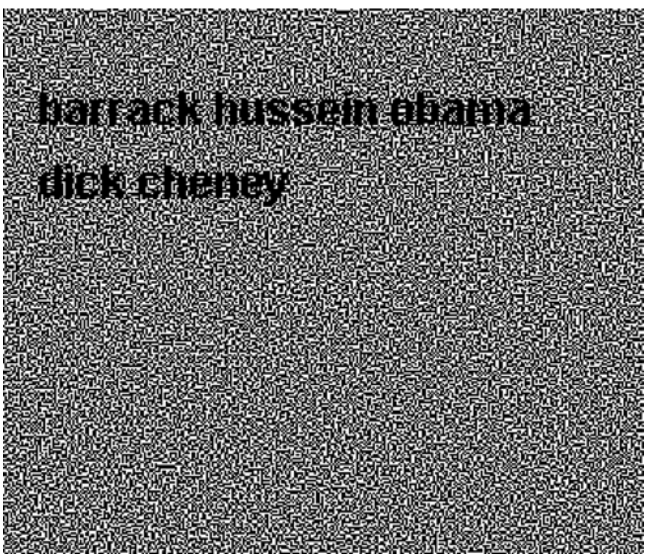

Fig. 7 eVote's sample ballot receipt

performance's standards, tests guidelines, system's components specifications, non-functional requirements, etc. In this paper we are focusing on the three main system requirements for E2E voting systems due to its importance. These three requirements that are to be elaborated below would then be used as some of the aspects to evaluate few E2E voting system in section "Comparison and Results". They are described as follows.

Functional Requirements

This particular requirement of electronic voting system covers the intended behavior of the voting system itself. Such behavior could be accomplished by completing few certain tasks or functions. It includes assurance over completeness, unreusability, eligibility, fairness of the system including its error handling mechanism, verifiability, soundness, robustness and its capability to ensure receipt-freeness is offered through an electronic voting system.

Usability Requirements

An electronic voting system must not only ensure its functionality standard, but it must also take its performance and user interface interaction into consideration. Regardless of the computational cost it has from the algorithms used to secure the system, it has to provide reliable and acceptable time allocation to complete the whole election processes as well. One of the aspects that could help the system to address this matter is by designing a voting system that accommodates common electronic voting system's usability standards such as accessibility, convenience and mobility.

Security Requirements

To accomplish all the necessary security requirements for an electronic voting system, in particular an E2E voting system is very critical. By implementing some cryptography schemes, the system could make sure that the voting system is secured to a certain legitimate level of security. In an electronic voting system itself, its security level could be determined by evaluating the following properties. They are privacy over data communication, system's integrity, anonymity, voter's authentication and ballot incoercibility.

Besides that, E2E verifiable also system emphasizes on incoercibility. Those features allow all of the voting system's users to verify that their ballots are truly casted, collected and counted through a specific receipt without assisting coercion attack over the system itself as well as divulging their ballots.

In this paper, some of the common attacks faced by E2E voting systems would be covered. Those attacks based on the sources are divided into two parts; internal and external sources [10]. Both of those parts are described in more details below.

1. *Internal Threats Sources*: A or threats by individual or groups who has the privilege to access the voting system equipment or its processes such as network communication are classified as attacks from internal sources [10]. Such attacks include deliberate and unintentional attacks [11] that threaten electronic electoral integrity. Deliberate attacks are often done by untrustworthy election officials or system's administrator. However, the voters themselves could also perform some attacks over the system, e.g. submitting invalid votes which will lead to undervotes, overvotes or even phantom votes. Whereby, unintentional attacks accidentally occurred due to poor system design and architecture or risks mitigation plan.
2. *External Threats Sources*: On the other hand, threats from external sources includes threats or attacks by individual or groups with no particular level of authorized access to the voting system equipment or the supporting infrastructure over the system itself [10]. Even without special access and privileges over a particular electronic voting system, external sources are still capable of facilitating malicious attacks. The possible risks are even higher for open-source electronic voting system as anyone with a certain technical and skills could analyze the whole election's procedure of an electronic voting system and determine its weaknesses and flaws. Once they are obtained, attackers could easily hack into the system mostly to manipulate the tally and disrupt the election processes including interfering data communication between the voters and the system's server. Some other attacks on E2E voting systems that have been reported include randomization attacks, forced-abstention attack, simulation attack, denial of service (DoS) attack, etc. They are to be elaborate in more detail as follows.
   a. Randomization Attack
      Schoenmakers detected this attack over Hirt and Sako scheme back in 2004 [7]. Its intention is to nullify the voter's vote by submitting as many forged ballots (randomly composed ballot material) as possible. Even if the attackers are not able to obtain the casted votes of the voters, they have coerced the voters' votes successfully.
   b. Simulation Attack
      All of the E2E verifiable voting system must ensure the prevention of coercion and vote's verifiability, one of the ways is by offering receipt-freeness. However, it actually does not eliminate the possibility of coercion to occur during the election period itself. Dishonest voters could sell their rights to vote by giving their private keys to the attacker who would cast the vote on their behalf. This is called the simulation attack.
   c. Forced-absention Attack
      Here, the attackers would attack the system by forcing the voters to refrain from casting their votes. By using the bulletin board as its reference list, attackers are able to identify the voters who are yet to cast their ballots and coerce them. This attack could be eliminated by restricting the bulletin board. Only eligible voters and other authorized election personnel are allowed to access and retrieve information from the bulletin board.
   d. DoS Attack
      Denial of Service attack is one type of cyber attacks that focused on disrupting availability [12]. It varies from physical IT environment destruction to make use of the system's flaws and overload the network capacity [12]. In E2E voting system, DoS attacks arise in all of the systems. It is rather difficult to prevent such attack, however they are easy to be detected. A very strong risks mitigation plan could help to avert the occurrence of DoS attacks in E2E voting systems.

Comparison and Results

Based on the system requirements and potential external sources threats described on the previous sections, in this paper we compare four different types of E2E voting systems that have been applied in medium to large scale real-world elections, namely Scantegrity II for Takoma Park Municipal Election, RIES public election in Netherland, the implementation of Helios voting system at Recteur of Universite Catholique de Louvain and lastly student council election at Princeton University that make use of Prêt à Voter system [13] along with our own proposed system. Each has its own strengths and weaknesses. In this paper, we did not perform comparison based on the internal sources threats due to the excessive number of possible threats that might arise without establishing some assumptions over the voting system itself. One of the common assumptions made by the voting system's designers or developers is to assume that the system users including voters, election officials, auditors, system administrators, etc are all trustworthy. However, because it is very difficult to ensure its validity

Table 1 Comparison of E2E voting systems based on its system requirements

Measurement		Helios	Scantegrity II	PV	RIES	eVote
System Requirements	Functionality requirements	High	High	Med	Med	High
	Usability requirements	Low	Med	Med	Med	Med
	Security requirements	High	Med	Low	Med	High

Table 2 Comparison of E2E Voting Systems based on its defense mechanism against common potential threats

Threats		Helios	Scantegrity II	PV	RIES	eVote
External Threat Sources	Randomization attack	No	Yes	Yes	Yes	No
	Simulation attack	Yes	No	Yes	No	Yes
	Forced-absention attack	Yes	Yes	Yes	Yes	No
	DoS attack	Yes	Yes	Yes	Yes	Yes

therefore internal sources threats are very difficult to be prevented from occurring in an election processes.

In this paper we present some results based on the comparison of E2E voting systems against three main voting system requirements, such as functionality requirements, usability requirements and security requirements and its vulnerability over common external sources attacks faced by E2E voting system, e.g. randomization attack, simulation attack, forced-abstention attack and DoS attack. Results are presented as shown in Table 1 and 2.

Based on our observation, analysis and research we are aware that generally E2E systems are not resistant to two external threats attacks used for the comparison purpose. They are forced-abstention attack and DoS attack.

These attacks are triggered by the main components of E2E voting system itself, e.g. due to its verifiability property, each of the E2E system must have a standard version of bulletin board to publish the voter's casted ballots in order to ensure the accuracy of the centralized ballot box. By supporting such feature, forced-abstention attack could take place. To eliminate or to decrease the possibility of its occurrence, the system's developers must restrict the visibility of the bulletin board. It should not be open for public, but only to eligible voters and the authenticated election officials. We have covered this in our proposed system; only the eligible users are allowed to access the bulletin board (read-only). Besides forced-abstention attack, most of the electronic voting systems are vulnerable to the DoS attack because of its large number of possible threats. Without a very strong defense mechanisms and risks mitigation plan, it would be very difficult for the E2E voting systems to prevent or to control this attack. This includes our proposed electronic voting system. This could be addressed in the future implementation of the proposed system itself. Other attack such as randomization attack is more vulnerable for paper-based ballot E2E voting system. Therefore, Prêt à Voter's integrity as a complete paper-based ballot E2E system is in jeopardize by its physical ballots. These ballots are susceptible from randomization attacks as attackers could easily replace the authorized ballots with the forged ones. In our proposed system, we offer the utilization of electronic ballots. Hence, randomization attack could be avoided. On the other hand, simulation attack often threatens those systems without polling officers' supervision and assistance. This kind of attack mostly happens to those remote electronic voting systems. Thus, our proposed system could be a subject to such attack as well if the voters cast their vote outside of the election officials' supervision.

Conclusions

In conclusion, electronic voting systems in particular E2E voting systems are not fully resistant over online attacks from the adversary. An E2E voting system can only fulfil a certain level of security. It cannot meet all the security requirements in an election without overlooking other necessary requirements it needs to support such as usability and functionality requirements. Different election environment, scale and user's skills as well as knowledge over information technologies itself would affect its system requirements. Thus, there is no such e-voting system that is entirely secure. This however should not be an obstacle for developing E2E voting system that is secure enough for the users and election conditions. Our proposed system is one of the many proofs that E2E voting systems are in demand and still in development. We believe that all of the combined cryptography and steganography schemes are sufficient to provide a secure, reliable and convenient voting system for a medium range election. Image steganography facilitates secure data communication between different users and the server. As for the cryptographic schemes, they support other E2E voting system's requirements—incoercibility and verifiability in particular. Future development includes its application in wider election range.

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Reliability Assessment of an Intelligent Approach to Corporate Sustainability Report Analysis

Amir Mohammad Shahi, Biju Issac, and Jashua Rajesh Modapothala

Abstract
This paper describes our efforts in developing intelligent corporate sustainability report analysis software based on machine learning approach to text categorization and illustrates the results of executing it on real-world reports to determine the reliability of applying such approach. The document ultimately aims at proving that given sufficient training and tuning, intelligent report analysis could at last replace manual methods to bring about drastic improvements in efficiency, effectiveness and capacity.

Keywords
Machine learning • Feature selection • Text classification • Document categorization • Supervised learning • Corporate sustainability report • GRI

Introduction

Maintaining sustainable corporate development has been an on-going issue for a long time ever since businesses figured out that business development was no longer about financial success, but also responsibility towards their hosting economies and the societies. With increase of public awareness thanks to the rapid development of mass communication technologies in 1990s, governments and local authorities started to require, or at least expect, businesses to adapt a responsible business approach. This meant that besides staying financially viable, businesses shall contribute positively to the overall economic, environmental and social wellbeing of geographical locations in which they operate.

As more reporting entities started to report on their social, environmental and economic responsibilities, it was immediately felt that having a reporting framework and guideline to be adapted and followed would be extremely beneficial for both report makers and analysers. The framework would provide a standard ground for developing and analysing the reports. Few organizations such as Global Reporting Initiative (GRI) and International Standardisation Organisation (ISO) have been actively involved in developing Corporate Sustainability Report (CSR) frameworks.

Since its initial introduction in 2000s, the third version of GRI's CSR framework (also referred to as G3) has gained the widest global acceptance to such extent that it has become the de-facto standard framework for CSR reporting [1]. The G3 framework addresses nearly all the aspects of economic, environmental and social responsibilities in a vast and generic way to be applicable to virtually all business domains. Furthermore, GRI has recently developed supplementary kits for certain domains to address their specific reporting needs. With majority of Fortune500 companies reporting their sustainability based on GRI framework, it could be assumed as the most effective CSR framework available to date [2].

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_31,

Reporting entities that choose to apply the GRI reporting framework need to declare the extent (level) to which the framework is applied to their reports. GRI Application Levels is a system using which reports can be self-declared to belong to any of the three levels, namely Level C, Level B or Level A. This is done to meet the needs of elementary reporting entities as well as the experts and those in between. Each level includes certain requirements to be met including the number of topics to cover in the reports. These requirements expand as the level increases from the elementary Level C to the extensive Level A.

As the number of published reports is increasing exponentially, one could easily see the need for an intelligent software system to help reporting entities and report assurance firms with scoring corporate sustainability reports.

This research paper discusses our efforts in developing such software system using machine learning approach to text categorization and is organized as follows: the following section will familiarise you with similar and related research and projects to draw a technical background. Section "Research Questions" defines the questions we had in mind before we commenced this research, which is followed by section "Research Methodology" in which the undertaken research methodology is described in detail. Section "Software Design and Setup" includes the engineering aspect of our software such as its underlying architecture. Section "Experimental Results" illustrates the results of running the software on actual reports to identify its strong and weak points. Section "Conclusion and Future Research" concludes this paper by summarizing the research process and results to draw suggestions for future investigations.

Related Works

Automatic scoring of CSR reports can be simply seen as a multi-class text categorization problem with standard disclosure indicators as classes. A CSR report can be broken down into multiple textual documents e.g. sentences, paragraphs to be considered for classification under either or none of the classes. This classification is carried out using the ontological characteristics of documents.

Text Categorization generally and the Machine Learning approach to it specifically have been subject to research aiming at solving various document analysis problems since their early introduction. Most of the research has been conducted on problems those of which being otherwise solved by manual means would be either too difficult, expensive or even infeasible [3]. These problems include (but are not limited to):

1. *Document Organization* [4] such as categorizing a news article under sports, politics, society, etc.
2. *Text Filtering*, which is implemented on either sender or receiver side involves determining whether a given document is suitable to be sent/received [5, 6]. A good example is the news corporations which produce news for their broadcasting clients. A client who publishes news regarding sports would not be interested in receiving news of any other topics, therefore the streamed news articles to this client shall be filtered at either the sender side or the client side.
3. *Patent application categorization* [7, 8] involves filing submitted patent applications under their respective categories, by studying the most important parts of the application such as the title and the first and last clauses, date of submission and applicant's name.
4. *Spam Detection tools* which perform Boolean classification of incoming messages by investigation their different components such as header, body, meta-data, etc. [9–11].

Extensive attention has been paid to development of technological infrastructure and tools for automation of generating CSR reports [12, 13] but developing an automated CSR report analysis system has been widely overlooked by the research community. Development of such system had been anticipated since the early days of GRI 3.0 [14] and it has been called to be highly desirable [15]. In our past research we developed methodologies and approaches using which corporate sustainability reports could be analysed and scored automatically [16–18]. This research explores building a software solution based on the developed algorithms and describes the results of its execution on at least 100 real-world reports.

Research Questions

Prior to commencing our investigations, we had two primary research questions to explore: Firstly it was not clear to us which text classifier algorithm or combination of algorithms would suit the CSR report analysis problem properly and secondly, how reliable a computer based report analysis would be when compared with its manual counterpart.

Thorough investigations had been done on various text classification algorithms and their results was published in [16–18]. We reported that using a chained classification approach i.e. combining Naïve Bayes with Decision Table classification algorithms produces top-notch classification effectiveness when facilitated with a correlation based feature selection algorithm. These efforts were in line with answering the first question. In this paper we report on the results of assessing the reliability of the software which we developed using the findings of our prior research. We were interested to find out the reliability level of our developed tool as a new step towards recommending an automated CSR report analysis solution.

Research Methodology

A GRI based corporate sustainability report shall report on at least 10 out of the mandated 49 disclosure items in order to qualify for Application Level C. In order to qualify for higher levels of B or ultimately A, reports shall disclose at least 20 or all of the 49 mandatory disclosures respectively. The framework also contains some optional disclosure on which reporting entities might choose to report instead if they aim at application levels B or C. Reporters may self-declare an application level based on the amount of disclosures in the report and publish through their preferred distribution channels. They could also go the extra mile and opt for having their application level claim get externally assured by GRI or a selected third-party firm authorized by GRI. Those reports which pass the external assurance step would be appended a "+" symbol i.e. their application level would be considered as C+, B + or A + .

Reliability Assessment

As the aim of this research is to determine the reliability of our software system, we chose 100 externally assured and self-declared CSR reports to be scored by our software. We would later compare the declared scores (Ω) with scores allocated to the report by our software (Ω'). The following hypothesis was assumed when conducting our tests:

Hypothesis 1. An automatic scoring would be successful if Ω' = Ω. However, it must be noted that as our software is unable to perform the external assurance on reports, it is not allowed to allocate a "+" symbol to calculated application levels. It is therefore safe to ignore the "+" symbol when comparing the claimed and calculated scores. For instance, an automatic scoring of a report to application level B would be considered successful if authors have published it with application levels B or B + .

Table 1 illustrates the frequency of claimed (or declared) application levels of reports we used for testing our software. By assuming Hypothesis 1 above, Table 1 is re-tabulated as shown in Table 2 below.

We would then apply the Pearson Correlation model to determine the correlation of scoring given by the organisations with software calculated scores.

In addition to testing the accuracy of overall application level calculation, we were also keen to know the effectiveness of our software in discovering information disclosures in reports. Hence, we picked 25 externally assured or GRI-checked reports which contained a GRI index of information disclosures and ran our software on them to figure out whether or not it is capable of discovering the disclosures mentioned in the report's attached GRI index table effectively. We used the following equation to calculate the Recall measure (R) of our software on each report in this matter:

Table 1 Declared application levels of tested reports

Application level	Frequency	Share (%)
A+	23	23.0
A	12	12.0
B+	14	14.0
B	24	24.0
C+	7	7.0
C	20	20.0
Total	100	100.0

Table 2 Equivalent application levels of tested reports

Application level (Ω)	Frequency	Share (%)
A	35	35.0
B	38	38.0
C	27	27.0
Total	100	100.0

$$R_i = \frac{TP_i}{TP_i + FN_i} \quad (1)$$

Where TP_i (or True Positives) represents the number of correctly identified disclosures as claimed in report *i* GRI index and FN_i (or False Negatives) shows the number of not-identified information disclosures in report *i*. The average software effectiveness was later calculated using the formula:

$$E = \sum_{i=1}^{N} \frac{R_N}{N} \quad (2)$$

Where, *N* is the number of tested reports (i.e. 100).

Classifier Training and Construction

Thousands of sample disclosures were selected from more than 100 CSR reports to create a classifier training corpus. We would later use this corpus to construct the text classifiers by making them observe the ontological characteristics of those sample documents. This would enable the classifiers to pick up the ontologies and feature correlations of each disclosure item, so than they can identify the most appropriate disclosure category for an

Table 3 Training size and algorithms used for each CSR dimension

Dimension	Classifier algorithm(s)	No. of training samples	Average number of samples/category
Economic	NaiveBayes	250	35.71
Environmental	NaiveBayes + DecisionTable	551	30.61
Social	NaiveBayes	809	31.11

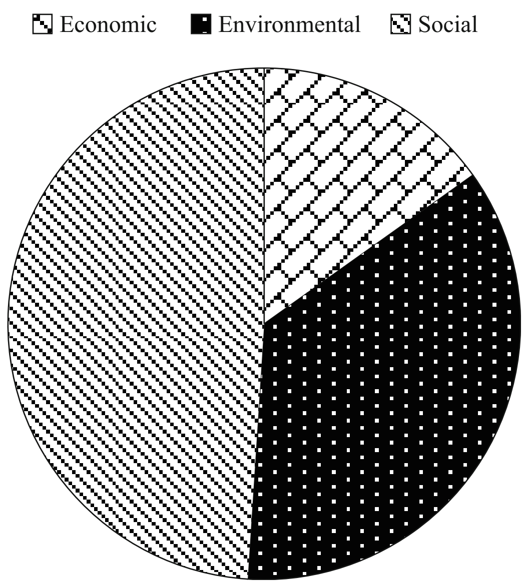

Fig. 1 Ratio of training samples per dimension

unlabelled document. We made sure that the CSR reports chosen for classifier training would not be used for classifier testing to avoid unrealistic testing results. Table 3 shows the size of the training corpus and classifier algorithms used for each of the three CSR reporting dimensions i.e. economic, environmental and social. The training corpus occupancy ratio of training sample for each dimension is shown in Fig. 1. As can be seen in Fig. 1, sample documents of the Social dimension occupy nearly half of the training corpus followed by those of Environmental and Economic dimensions. This is due to difference in number of disclosure items (categories) in those dimensions.

Software Design and Setup

The proposed software was designed using the modular approach to software architecture with each module performing an interdependent task while interacting with others. The Three-Tier architecture model is embraced to isolate various functional components of the system into Data, Logic and Storage tiers as suggested in [19]. The logic tier of the system consists of three major interdependent modules namely Office Interoperability, Text Mining and GRI. Additionally, the system architecture features various data storage and data feeding capabilities, which provide certain system components with required operational data as well as information presentation and storage interfaces.

All operations are carried on by collaborating and exchanging data with other two modules i.e. the Text Mining module and the GRI module. They are respectively in charge of categorizing report sections under appropriate performance indicator categories installing, processing and rendering the scoring framework (i.e. GRI) to determine the extent to which the framework has been applied. An overall view of modular architecture of the proposed system is illustrated in Fig. 2. The Office Interoperability module contains processes which are designed for report file format conversion and formatting. This involves converting PDF to Microsoft Word format, creating necessary data, as well as exporting the final scoring report in Microsoft Excel format. The diagram in Fig. 3 below elaborates the dependencies between the namespaces of the software.

As apparent, the software is developed as an add-on for Microsoft Word 2010 which enabled us to enjoy its powerful text interpretation features. A Word 2010 document is hierarchically broken down into pages, paragraphs, sentences and words (See Fig. 4). This sophisticated object model enables interpretation of textual documents at any desired scale (e.g. paragraph by paragraph or sentence by sentence). As most of CSR reports are published in Portable Document Format (PDF), we developed an extra module which would convert PDF reports into Word 2010 documents. The documents will be opened in Word 2010 to be subject to automatic GRI application level determination (scoring) using our developed Intelligent Tagging Engine (or IntelliTag). IntelliTag consists of three classifiers (i.e. one for each dimension) named as Economic Classifier, Environmental Classifier, and Social Classifier. These are all immediate children of the abstract Text Classifier Engine class. Each of the above classifiers is composed of one or two text classifier algorithms as mentioned in Table 3 above. The class diagram in Fig. 5 presents this architectural idea visually.

Immediately after receiving user's command to commence the intelligent scoring process, IntelliTag starts to construct a classifier model using the supplied training corpus or de-serialises a pre-serialised model from the supplied binaries based on user preferences. After classifier model construction (or loading), IntelliTag iterates through the

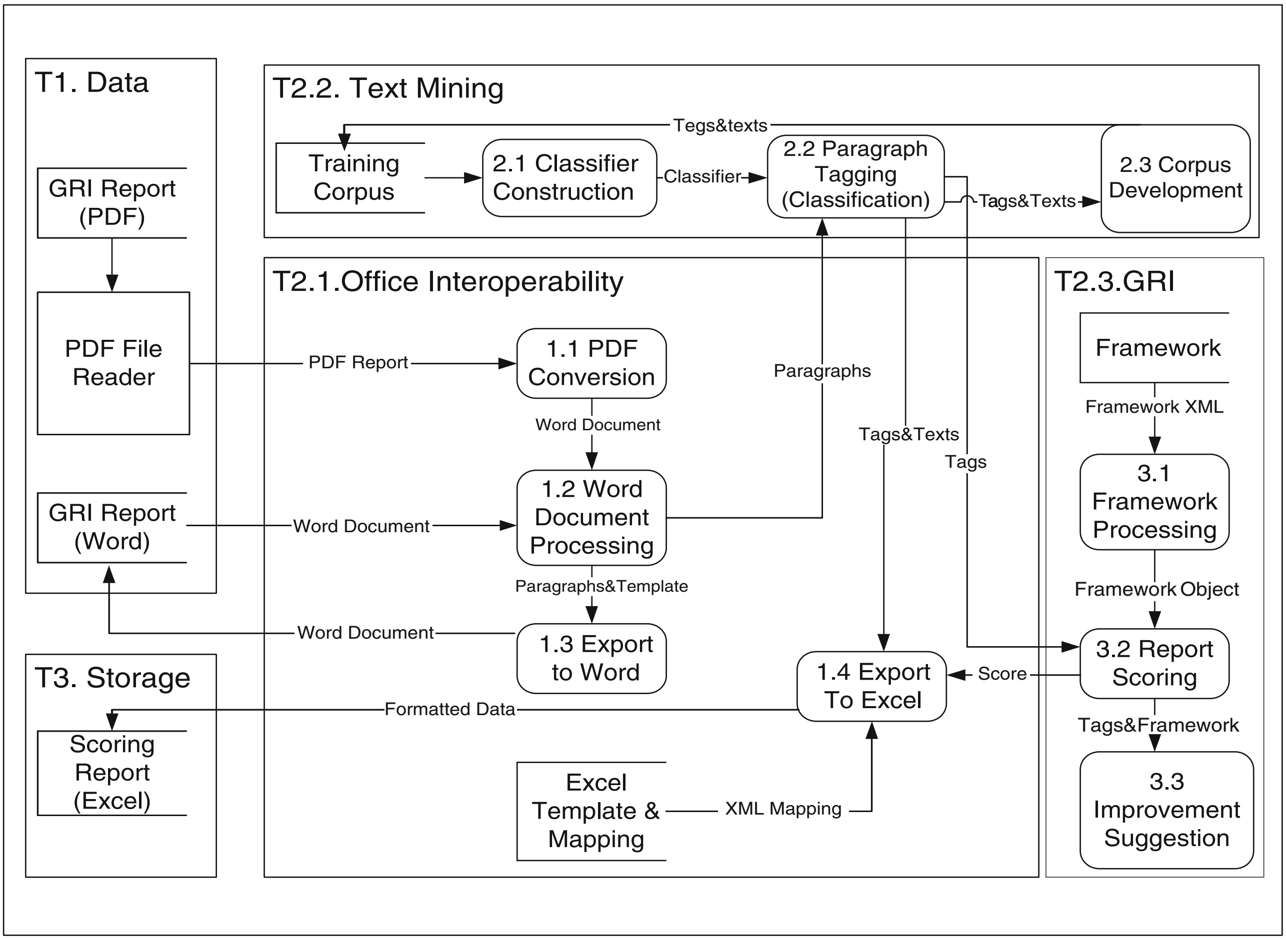

Fig. 2 Three tier system architecture

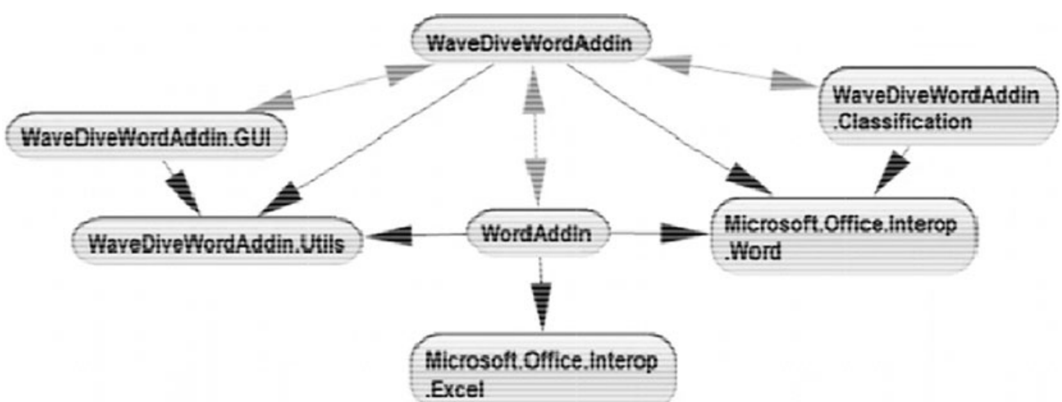

Fig. 3 Internal namespace dependacy diagram

document on a paragraph by paragraph basis and treats each paragraph as a candidate document to be classified under either or none of the model categories (or disclosure items).

Each candidate document shall pass by a stop-words filter and a correlation-based filter before getting processed by the selected document classifier.

Finally, the scoring module is triggered to determine the extent to which GRI G3 framework has been applied to the report. The results of the scoring process as well as details of discovered information disclosure items (such as their page number) are exported to a Microsoft Excel 2010 formatted file.

Experimental Results

As mentioned earlier, we measured the effectiveness of our software by comparing its accuracy in calculating the correct score (or application level) as well as discovering correct disclosure items in reports. These results are also referred to as *aggregated results* and *atomic results* respectively.

Aggregated Results

Aggregated results are calculated using Pearson product-moment correlation coefficient measure (Pearson *r*) by measuring the linear dependence between the claimed application levels (also known as Equivalent application level) and scores calculated by our software (also known as WaveDive application level).

Table 4 shows the results of running our software on test reports. As can be seen, none of the reports have received Application Level A while 42 of them were automatically scored as Level B and 51 as level C. Seven reports were not determined to qualify for any application level.

According to Table 2, 35 of the reports had been declared to qualify for application level A and A + by their authors; however, by looking into their attached GRI index tables we could not help but notice that none of them are inclusive of all the required disclosure items. Instead, they contain references to external resources such as company websites for some disclosures. Although this method of reporting is totally accepted and permitted by GRI standards, the software is unable to follow the links to those external resources and fetch the resulting data for classification. It means that according to the software, these reports do not contain sufficient disclosures -within them- to qualify for their declared application levels. This limitation is the main cause of underscoring some of the tested reports to a lower application level. Nevertheless, no over-scoring (determining a higher application level than declared) was witnessed.

Using Statistical Package for Social Sciences (SPSS) Pearson correlation (*r*) was calculated between WaveDive application score and Equivalent application score. It is found that the correlation between the selected variables is 0.531 and is significant at 0.01. The correlation of 0.531 is considered 'moderate'.

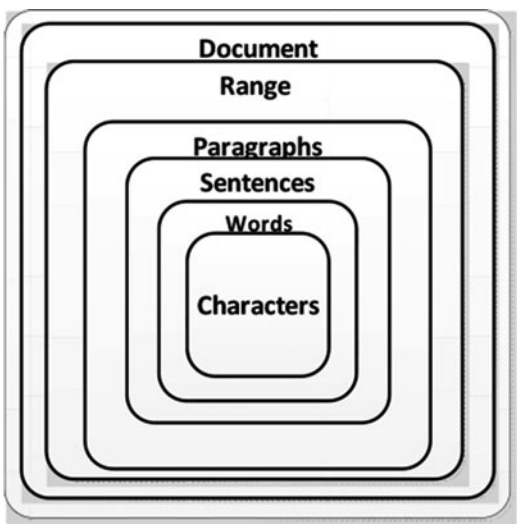

Fig. 4 Word 2010 document object model

Atomic Results

The atomic results were calculated by comparing the discovery of information disclosure by software and actual disclosure claims by reporting entities on a disclosure-by-disclosure basis. A disclosure discovered by software which has been claimed to be reported by report author is counted as a True Positive while skipping a claimed disclosure is counted towards False Negatives. The Recall measure for each report dimension is calculated as in (1) before calculation of overall accuracy as in (2).

Table 5 below shows the number of true positives, wrong negatives and Recall measure of the software in discovering disclosed information in each dimension of the selected 25 reports. These results are illustrated visually in Fig. 6 below.

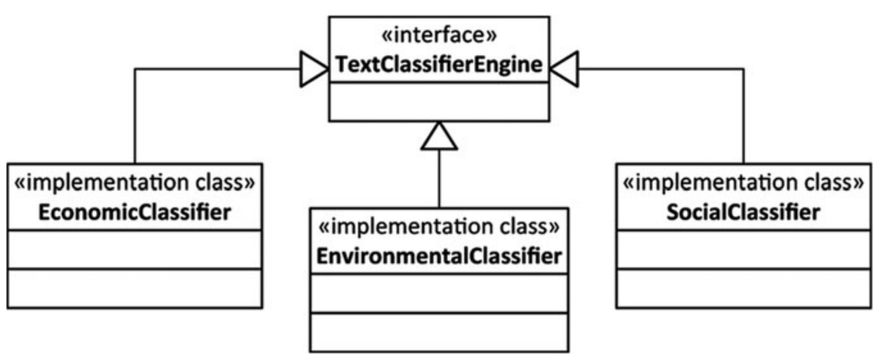

Fig. 5 UML architecture of intellitag component

As expected, effectiveness on Environmental dimension was higher than on other dimensions mainly due to adapting a chain classification approach and combination of stop-words and correlation based feature selection. The Social classifier is second most effective followed by Economic classifier, which shows an overall effectiveness of 73.71 %. This happened despite higher number of Economic training samples compared with those for the Social classifier (see Table 3). We believe that it is due to high ontological similarities between Economic disclosures, which cause classification confusion [17]. The Social dimension, although bigger in terms of number of categories, has several ontologically-distinctive category clusters. This enables composing a more efficient classifier model and producing better results. It is wise to calculate the overall effectiveness of the software in information discovery as an average of Recall measures in Table 5. Therefore, information discovery effectiveness (E) is:

$$E = 81.10\,\%$$

Table 4 WaveDive calculated application levels

Application Level	Frequency	Percent	Valid percent	Cumulative percent
B	42	42.0	42.0	42.0
C	51	51.0	51.0	93.0
None	7	7.0	7.0	100.0
Total	100	100.0	100.0	

Table 5 Atomic results of execution on selected reports

Dimension	No. of disclosure items	N	TP[a]	FN[b]	Recall (R) (%)
Economic	7	25	129	46	73.71
Environmental	17	25	391	34	92.00
Social	25	25	485	140	77.60

[a]Number of true positives
[b]Number of false negatives

Conclusion and Future Research

This research is the first of its kind to determine the suitability of machine learning approach to text categorization for development of automatic corporate sustainability report analysis software. By dividing a corporate sustainability report into three report dimensions i.e. economic, environmental and social we constructed three intelligent text classifiers as building blocks of our proposed software. The results of executing the software on 100 quality CSR reports shows that this approach is moderately reliable and has a promising potential for further improvements and research effort.

By reaching an overall 81.10 % effectiveness in disclosure discovery it is observable that given sufficient training and development, developing a highly reliable automatic report analysis solution is feasible and within sight. We will work further on improving the overall effectiveness by creating higher quality classifier training.

One of the limitations of the current software is its inability to distinguish between chapters of a report and requires the operator to provide it with chapter starting and ending page numbers. In future, we will explore the possibilities of creating a solution with automatic report dimension (or chapter) detection to mitigate human intervention and improve mass report analysis capabilities. We are also keen to discover a reliable solution to fetch externally referred information to be subject to classification. This would improve the correct application level determination rate. By using the capabilities of this software solution, it

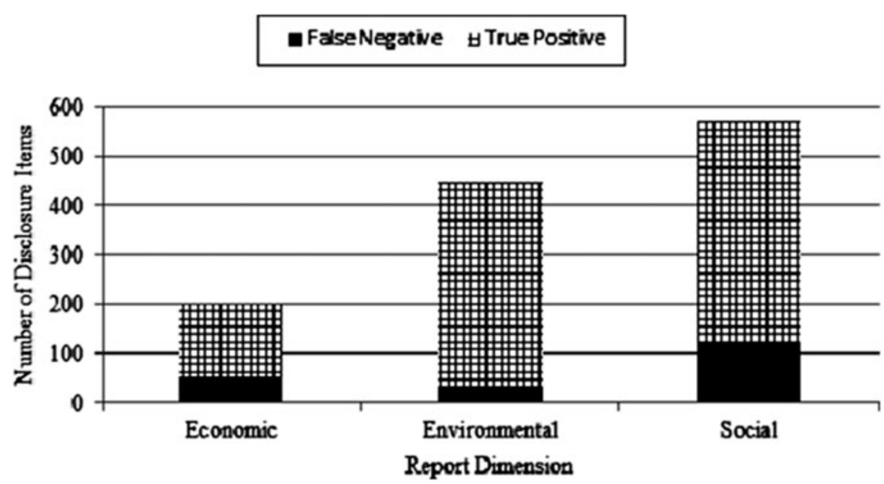

Fig. 6 Atomic results of execution

will be possible to analyse a considerable amount of CSR reports and conduct studies such as reporting pattern identification among businesses of various sizes, regions and sectors. This could be done by identifying the most and least popular disclosure items and dimensions among the studied businesses.

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Ubiquitous Text Transfer Using Sound a Zero-Infrastructure Alternative for Simple Text Communication

Kuruvilla Mathew and Biju Issac

Abstract

Even in these days where data networks has increased much in terms of speed, bandwidth and penetration, the need for a low power, low bandwidth, ubiquitous networks is more pronounced than ever before. As the devices get smaller, their power supply is also limited, in according to the definition of "dust", "skin" and "clay" in the ubiquitous computing paradigm. The possibility of these devices to be present in real world depends a lot on the key capability they must possess, which is to be network enabled, ubiquitously. This paper looks at the possibility of using the ever present signal "sound" as a ubiquitous medium of communication. We are currently experimenting on various possibilities and protocols that can make use of sound for text transmission between two electronic devices and this paper looks at some attempts in this direction. The initial phase of the experiment was conducted using a very large spectrum and encoding the entire ASCII text over audible sound spectrum. This gave a very large spectrum spread requirement which a very narrow frequency gap. The experimental results showed good improvement when the frequency gap was increased.

Keywords

Ubiquitous computing • Network • Text transmission over sound

Introduction

The presence and developments the world is witnessing to the IEEE 802.15.4/Zigbee protocols are clear indications to the direction in which the future of mass-computing is headed. While the power of computing keeps increasing on the desktop PC front more or less in tune with the Moore's law for many decades now, the increase in the scale of VLSM is also allowing devices to be smaller. This allows the concept of "ubiquitous computing" [1] to be a reality whereby it allows the devices to be as small and unobtrusive as required. The concept however shares that this will definitely allow much greater penetration in the market.

This paper looks at using some ubiquitous signal for data transmission. Sound was identified as a very common, easy to generate, low power signal and the attempt is to transfer data using sound frequency encoding [2]. Combining this with the fact that in the modern day environment almost all average (urban) population is exposed to some device that generates or receives sound (the mobile phone being a classic example), makes it an ideal ubiquitous signal.

The first round of the experiment directly converted text into audible frequency with a 3, 5, 7 and 10 Hz gap. Increasing the frequency gap gives very good results, but this caused the spectrum used to be much wider. The paper identifies the capability of using sound for

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_32,

simple text transmission between two devices, leveraging the large spectrum of available spectrum of sound frequencies.

The paper is organized as follows. Second section is related works, third section looks at the need and possibilities, fourth section shows the idea and experiments done, fifth section is evaluation and summary and the last section is conclusion.

Related Works

M. Weiser, in 1991 proposed ubiquitous or pervasive computing as technologies those that disappear as they weave themselves into the fabric of everyday life until they are indistinguishable from it [1]. He introduced concepts called tabs, pads and boards which we see in common use in today. Weiser also opens up the networking challenge the nature of the devices will present.

Anil Madhavapeddy, David Scott, and Alastair Tse looked at audio networking as a forgotten technology [2]. They used audio in order to send and receive data and were also able to make use of common computing platforms to achieve high frequency (ultrasonic) communication at low bandwidth.

Chen, T. T., & Lee, M presented a bibliographic study of the Ubiquitous Computing prospect looking at the major research themes and in ubiquitous computing and their inter-relationships [3]. This paper reveals that the majority of the studies relate to basic foundational studies of ubiquitous computing, power aware computing, context aware computing etc.

Jurdak, R., Lopes, C. V., & Baldi, P. discussed an acoustic identification scheme for location systems [4]. The paper looks at the design of using acoustic signals to uniquely identify and locate a user.

Madhavapeddy, A., Scott, D., & Sharp, R. presented context aware computing with sound [5]. The paper presents a variety of location- and context-aware applications that use audio networking including a location system, a pick-and-drop interface and a framework for embedding digital attachments in voice notes or telephone conversations.

Luo, H., Wang, J., Sun, Y., Ma, H., & Li, X.-Y discussed wireless audio sensor networks (WASN) that can provide event detection, object tracking audio stream monitoring etc. the proposed scheme works on improving signal recovering fidelity with low energy costs [6].

Shah, R., & Yarvis, M. presents experiments carried out over on-body networks or body area networks and experiments on how the node location (on the knee, heel etc.) as well as body position (sitting, standing, lying down etc.) affect the connectivity properties in the network [7]. The system looks at the IEEE 802.15.4 radios for the low power networking technology.

Chen, W., Hou, J., & Sha, L. presented a fully decentralized, light-weight, dynamic clustering algorithm for target tracking in wireless sensor networks [8]. The paper's proposed dynamic clustering algorithm effectively eliminates contention among sensors and renders more accurate estimates of target locations as a result of better quality data collected and less collision incurred.

Mandal et al. attempted to makes use of audible sound for indoor positioning based on standard 3D multilateration algorithms [9]. It is able to work with an accuracy of about 2 ft in almost 97 % of the cases using standard cheap consumer use hardware.

Ubiquitous Computing Networks: The Need and Possibilities

Ubiquitous definition makes some devices very small with very limited power supply [12]. The devices may be too small to allow a physical communication interface or ports. Hence it is desirable, even necessary, that each of these devices should be able to connect and communicate with its neighboring devices and/or central concentrators using some wireless technology. The device communication requirements may be limited, ranging from as simple as transmitting its own id to notify the presence of an attached resource to some basic data transfer to begin with. Since the present capability of the communication devices is assumed to be limited, transmission of very large data is not an expectation from the system.

Such a system can be very useful in conditions where a large infrastructure is either not available, not feasible due to economic or technical limitations, or simply for the sake of convenience. Some possible application of the system is in remote locations where large scale infrastructure with very large power requirements may have its own practical limitations. It may also be employed in a crowd to push transfer messages ubiquitously to a selected group of users who may be carrying a decoding device and hence can be useful in large conference type of events. It can be used by shopping malls desiring to advertise the presence of various stores within it along with special offers. They can be employed in hazardous environments [13] like underground mines, expanding it as a zero infrastructure ubiquitous sensor network, can provide much more than life saving critical system, it can be a communication tool for administration and management and even for social networking.

Current wireless networking technologies rely on either microwaves or light as the medium for signal transmission. Microwave technology works by modulating the signals to be transmitted over high speed and high frequency microwaves, which are then relayed between the sender and receiver devices with the help of transponders. This usually requires some amount of infrastructure setup ranging from small Wi-Fi networks to Wi-Max, which can cover major metropolitan areas, and also requires lots of battery power which is required to create the high strength signals. Optics or use of light has been in use for a good amount of time. Classic examples of low bandwidth data transfer using light is the infrared. Infrared is capable of making low bandwidth data transfer in short distances, however with the requirement of a clear line of sight as light only travels in straight lines. This bottleneck imposes serious restrictions in the use of light as a signal for wireless data transmission. This also imposes that the devices are equipped with infrared signal generators and sensors.

Using sound as an alternative can provide us with a low bandwidth, low power alternative to the current signals in use, eliminating the need of any specialized components to be included either generate or receive the signal. The category of devices we are looking to consider is already expected to be equipped with both the speaker and the microphone as essential accessories of the devices. The generation of sound is also not as power consuming as the higher power signals are thus making them more power efficient, but this also restricts the distance the signal can travel. The speed of sound is much slower in comparison to both microwaves and light but this can prove to be sufficient for low-bandwidth solutions requiring the transfer of plain textual character data as experimented in this paper. Current common communications generally does not make use of sound as a signal carrier and hence specific security and reliability considerations needs to be evaluated.

However, one issue to be expected when using ubiquitous signal is the fact that the signals are already present in the environment. This multiplies the effect of noise and interference [11] on the communication. However, the bandwidth being quite high, we can always shift the frequency to a different range to find a quieter band. In any environment we should be able to apply some kind of noise gate to filter out the noises. This will be a major challenge in the presence of "white noise" which contains all frequencies in relatively equal levels. Another issue in using sound is that it creates humanly perceivable signals. This can be disturbing, even unacceptable for some communities. We may be able to work around this by exploring the possibilities of using the sub-sonic and ultrasonic frequencies. Sound on the other hand comes with zero radiation and hence should be a much safer signal for society.

Networking Using Sound: Idea and Experiments

The Idea

The current networking technologies work on microwaves, which are both, high power consuming and non-ubiquitous. More often they require a good amount of infrastructure setup before they can start functioning. In this paper, we are looking at achieving low bandwidth data transfer using sound signals. Sound signals can usually work on very low power, allows a very good control on range by controlling amplitude, and meets the ubiquitous constraints.

The initial attempt is to send plain ASCII text as beeps of varying frequencies. If the frequencies are sufficiently spaced, then any standard microphone can pick up the frequencies. These can then be decoded using standard algorithms such as the Fast Fourier Transform (FFT), which is what we have tried for our experiment [10].

Fast Fourier Transform or the FFT algorithm is a discrete Fourier Transform algorithm that can be used to determine the fundamental frequency of a captured signal. This audio signal is recorded and the FFT algorithm is applied to find the frequencies encoded in the signal. It is used to transform the original audio data into the original text. The FFT exploits the fact that a periodic signal will be similar from one period to the next. FFT algorithm has two sections, first section sorts data in bit reversed order. The second section has an outer loop that is executed log2 N times and calculates, transforms of length 2; 4; 8; . . .; N. For each stage of this process, two nested inner loops range over the sub-transforms already computed and the elements of each transform, implementing the Danielson-Lanczos theorem [10]. FFT transform source code by Aleksey Surkov was used in our experiments.

For the first attempt we are looking at encoding ASCII data as sound frequencies. This gives us an effective range of values from 0 to 127. The audible range of sound that can be picked up by a microphone is quite large and hence gives us a good range of frequencies to work with. To keep things simple to start off, we picked up a frequency gap of 5 Hz starting from 500 Hz. The text was encoded using a simple encoding scheme, given as follows:

$$f = (a + sh) * g \tag{1}$$

f: frequency in Hz,
a: value in ascii,
sh: Freq Shift
g: frequency gap between two ASCII codes

"a" is the code in ASCII which we intent to transmit. "f" is the frequency of the encoded data. We apply a frequency shift parameter to be able to move the data transmission band up or down on the audible spectrum. "g" is the frequency step gap, which forms the gap between two consecutive codes.

According to this scheme, the character "A" will be sent as a beep of (65 + 100)*5 = 825 Hz, assuming a 5 Hz gap between each consecutive code. This will use a spectrum ranging from (0 + 100)*5 = 500 Hz to (127 + 100)*5 = 1,135 Hz. If we increase the gap factor, it is expected to give a better accuracy, but will use a larger bandwidth, between 1,000–2,270 Hz.

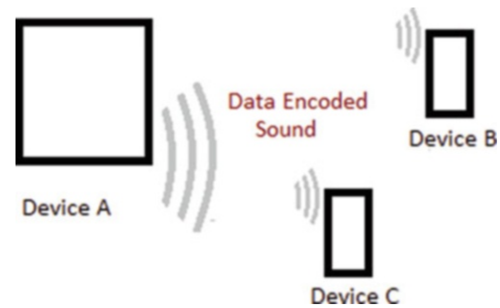

Fig. 1 Block diagram of the experiment setup

Experiment Setup

We used some very commonly available devices for the experiment, some Smartphones and tablet PCs, all running the Android OS. The hardware used included the Samsung Galaxy Nexus running Android 4.1.1 (Jelly Bean), Samsung Galaxy SII running Android 2.3.3 (Gingerbread), Samsung Galaxy tab 10.1 running Android 3.2 (Honeycomb), Toshiba Thrive running Android 4.0 (Ice cream Sandwich) and a very old HTC Magic running Android 1.6 (Donut). All devices were able to participate in the communication dealing with the audio signals with more or less equal clarity.

Fig. 2 Experiment setup—the devices

An application to send text and another one to receive text was created. The send text application will receive plain text user input and convert it first to ASCII, use the function (1) to convert it to the frequency code and then generate the tone as a beep. The receiver application will listen actively and when it receives a tone, it will apply the Fast Fourier Transform (FFT) algorithm to identify the frequency of the tone. The reverse of function (1) is then applied to decode the actual ASCII value, which is then converted to plain text and displayed on the UI screen.

Figure 1 shows the block diagram of the experiment setup where data is encoded as sound and sent from device A using its in-built speakers and received using devices B, C etc. The signal in use is data encoded as sound signals, medium of transmission is air at room temperature. Sound is generated using standard speakers build into the devices and received using standard microphone, also built into the devices. The devices are expected to always ship with these components as standard accessories.

Fig. 3 Experiment setup—data transfer

Figure 2 shows the devices used for the experiment, each of them showing the application in the foreground. The data transfer is more of the broadcast nature and therefore when one device transmits data, all listening devices can receive the data.

Figure 3 shows the successful data transfer between the transmitting device and one of the receiving device. The text "TEST" is sent with a 5 Hz frequency step gap and frequency shift of 100. The text is transmitted from Samsung Galaxy Nexus running Android Jelly Bean and received on a Samsung Galaxy SII running Android Gingerbread.

The success rate in using a larger gap was much higher than if using smaller gap. However this used a much larger

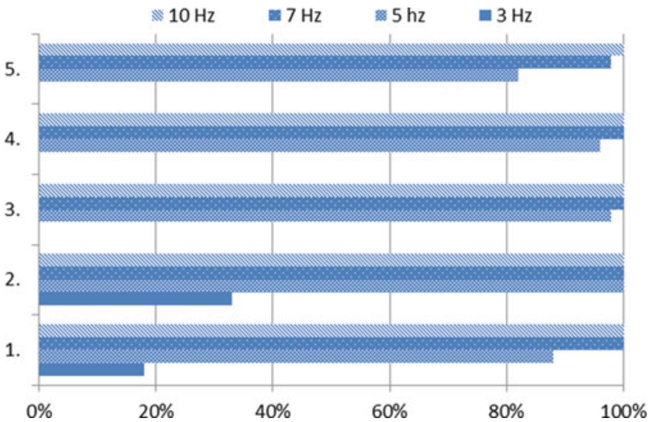

Fig. 4 Chart—comparison of the test experiments

Table 1 Test character transmission results

No	Test condition	Success rate with steps of			
		3 Hz (%)	5 Hz (%)	7 Hz (%)	10 Hz (%)
1.	‘A’, ‘E’, ‘J’, ‘O’, ‘T’, ‘Z’	18	88	100	100
2.	‘0’, ‘5’, ‘9’	33	100	100	100
3.	‘A’ to ‘Z’	–	98	100	100
4.	‘0’ to ‘9’	–	96	100	100
5.	Random characters	–	82	98	100

spectrum, making it more susceptible to ambient noise. This was not an issue in the test environment in the lab and will become more prominent in “noisy” environments. This may also be considered as a risk in using a ubiquitous signal, as by definition, the signals are present in the environment and hence more susceptible to noise.

Elementary testing for the data transfer using 3Hz gap caused too many errors to even do an acceptable testing. However, the 5Hz gap gave fairly acceptable success rates to perform a reasonable testing. When the gap was increased to both 7 % and 10 % the errors in transmission of text characters were drastically reduced. The test transmission the above cases are showcased in the following chart.

Figure 4 shows the chart comparing the success for each of the cases in Table 1 in transmission of characters. We can see the success increases when the gap also increases. 7 Hz gap gives very high success. If a good error detection and feedback mechanism can be implemented, then a frequency gap of 5 Hz may also be acceptable, as applicable to the context.

Evaluation and Summary

The experiments effectively establish that it is possible to make use of sound as signal for communication, thought there is a lot of room for precision and improvement. This brings forward sound as a potential ubiquitous signal for low bandwidth communication. The signal also allows fine grained control over distance since the amplitude or strength of the signal determines the travel distance. Furthermore, rooms can be designed to be soundproof to contain the audio signals within defined premises [2].

One possible negative effect of this signal is the noise pollution that widespread use of this technology may create. However, this may be considered far less dangerous than the radiation levels the currently existing mobile infrastructure brings with it to the society. The effect of noise may also be very well addressed using either ultrasonic or infrasonic (sub-harmonic) frequencies, but this may require more specialized hardware which can produce and respond to frequencies in this supersonic or sub-sonic ranges.

The possibility of using this signal in high noise environments still needs to be experimented. As in any signal, presence of noise can cause interference. This is definitely one issue to be anticipated when using signals of the ubiquitous nature as similar signal are expected to be present in the ambient environment. One possible method to circumvent this is by making use the very large range of frequencies that is available in the audio spectrum, wherein we may be able to find a frequency band which is relatively quiet and make use of this band for the communication. This dynamic band for transmission can be identified by the transmitting device and setup between all participating devices.

Sound is therefore a positive candidate as a network communication signal. Some more refinement needs to be brought in before this can be introduced into widespread use.

Conclusion and Future Works

The attempt for a ubiquitous signal for use within a ubiquitous network is still in a very early stage. The current experiments help us understand the capability of sound as a signal for communication. We were able to successfully send out a text encoded sound. This data was received by all capable devices used for the experiment. The devices were all running on the Android platform, but were all of different capacities and form factors ranging from a smart phone more than 3 years old to the latest and relatively much faster 10.1 in. tablet pc, from an old version (Donut) to the latest version (Jellybean) of the Android OS. Each of these devices were able to handle the text transfer with ease, proving that the technology can be deployed with relative ease, subject to good development and establishment of the communication protocol.

This work still requires more experimentation, evaluation and establishment of a workable and practical protocol. Future work in this area will focus on experimenting further to identify efficient communication strategy. The performance for this in various ambient conditions, including "noisy" environments, will vary and detailed study in this realm is called for before this can emerge as a workable practical protocol for everyday use. Once established, this has the potential to emerge as a low cost, low bandwidth, short distance communication medium.

Acknowledgments We thank Aleksey Surkov for the source code which uses FT for pitch detection. The source code was available at http://code.google.com/p/android-guitar-tuner/source/browse/#svn%2Ftrunk%2Ffft_jni

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Web Based Testing in Science Education

M. Hostovecky, M. Misut, and K. Pribilova

Abstract

The paper describes the analysis and characterization of partial results (mathematics) research, which focused on the issue of detection of key knowledge and skills of pupils and students in primary and secondary schools in selected regions in Slovakia and the Czech Republic (the border area between the two countries). The aim was to determine whether there are regional differences and gender differences in mathematical competence. At the same time develop and test a suitable tool to effectively detect these differences. The results are currently being further analyzed in the context of educational programs and policies, along with cross-curricular links with a view to identifying the causes of the existing differences. The results of this research are also applied in the implementation of research-oriented implementation of a virtual excursions, supported by a grant KEGA.

Keywords

Competences • Mathematics • Web • Assessment • ICT

Introduction

Nowadays, computers and other information technologies have a very important place in the learning and teaching process. Computers are also an integral part of students' everyday life outside of school and within school, they are used in writing homework or essays, within every school subject, not only in informatics [1].

Initially, computer technology was viewed as a way to improve students' access to instruction and instructors. The vision was that computer hardware and software would make teaching and learning better and more effective [2]. Before this can happen, students, and teachers too, have to see the greater value of using computers in lessons [3].

The European Parliament defined the key competencies as: "a combination of knowledge, skills and attitudes appropriate to the context. Key competences are those which all individuals need for personal fulfilment and development, active citizenship, social inclusion and employment". The Reference Framework sets out eight key competences with the definition of digital competence among them. Digital competence involves the confident and critical use of Information Society Technology for work, leisure and communication. Developing of basic skills underpinned by developing of digital competences is based on knowledge of computer technology and using it for editing, processing and communicating information and supporting collaboration for cultural and professional purposes [4, 5].

There is significant role of pupils' assessment in the learning and teaching process. Using information

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_33,

technologies opens new scope in pupils' assessment. Educational institutions use various automated electronic systems for verifying of pupils' knowledge. There are many scientific studies devoted to electronic assessment of pupils' knowledge and skills. Current electronic systems for pupils' knowledge assessment are described in studies as well as advantages or disadvantages of using it in the learning and teaching process. The results demonstrate that these systems can be very beneficial, especially for large science classes, and can be deployed at minimal cost [6–11].

Using of multiple media in digital assessment systems allows not only the review of factual knowledge, but adds the assessment of competence levels and the decision-making processes of students [12].

Having formative character the electronic assessment is oriented to knowledge and conscious development of each pupil. Thanks to Information and Communication Technologies all types of didactic tests can be currently realized online in most of basic and secondary schools. The authors of test tasks in cooperation with programmers can create such types of task that can be realized within the process of testing [13, 14].

Horne (2007) found no difference between boys and girls on testing students with the use of computers. Interaction between gender and technology is complex, being mediated by a number of factors, such as status and identity [15].

A large number of studies have shown that those individuals who have access to computers at home demonstrate more positive attitudes toward computers [16–19].

Research Description

Current research named "Knowledge and skills diagnostics of pupils with a focus on their development" and it was realized from September 2008 to August 2011. Main research institution was "Metodické a evaluační centrum, o.p.s." in cooperation with the Trnava University in Trnava (Slovak Republic) and the University of Ostrava (Czech Republic). Project was funded by the European Regional Development Fund of the European Union.

The main goal of research was knowledge and skills assessment (within input and output tests) of pupils in third, fifth and seventh class of basic schools and students in first class of secondary schools in such subjects as math, native language and natural science in range of 6,400 students in pre-selected regions in the Slovak Republic and the Czech Republic. Current assessment was realized by developing of software for assessment for the subjects mentioned above for each class. The particular goal was investigation of the relative increasing of pupils' and students' knowledge and skills in all of the mentioned subjects by adaptive testing method in output testing. In this paper we introduce some results of research concerning on the math, considering the amount of acquired data, carrying out analyses and considering the location of authors. Border schools participating on the testing in both countries enlist as a volunteers based on newsletter sent to headmasters to all basic and secondary school in the region.

Research was divided into several phases. First *phase of analyses and expert discussions*, which resulted into the decision in which methodologists and experts on education set two groups of subjects: humanities subjects and natural science subjects. Group of natural science subjects covered math, physics, biology and chemistry. The group of natural science subjects was designated as natural science basis. Group of humanities subject consist Czech language (for students from the Czech Republic), Slovak language (for students from the Slovak Republic) and foreign language either English or German (students could choose one).

Second *phase development of testing software for students' testing and teachers' training*. Discussions among development team and educational experts on particular subjects preceded the software development. The discussions resulted into the design of graphical environment layout and controlling system of testing, into the way of running and executing the selected subjects testing, into the way of assessment and into the way of generating test results into the output reports. Reports were generated for students, parents and headmasters of school. Development of the software and pilot verification took one and half year.

It was necessary to take attention to hardware equipment of schools (Internet connection speed, hardware configuration used by pupils, screen size) before the software development. Having done software for testing it was necessary to verify functionality of the software in real situations in basic or secondary schools. Verification of software was realized by pupil respondents represented each class (third, fifth and seventh class of basic school and first class of secondary school) within two basic schools and two secondary schools. After the finishing of verification there were eliminated revealed faults. Training of the teachers followed after the eliminating of faults. This was realized by tutors at each school enlisted in the project. Tutors were teachers of Departments of Mathematics of both Universities participating in the project. Objectives of the training were set for preparing teachers of basic and secondary schools onto pupils testing and helping pupils to work with the testing software.

Third phase was *determining the particular mathematical competencies for each class* based on curriculum of math in accordance with competencies recommended by the European Parliament and the Council of the European Union since 2006. Experts appointed that competence to be acquired by students since previous period of learning, they determined following mathematical skills:

Table 1 Differences in skills no. 6–15 of mathematics

	Wilks' lambda	F	DF effect	DF error	P	η^2
Country	0.907	17.958	9.000	1,577.000	0.000	0.093
Sex	0.979	3.753	9.000	1,577.000	0.000	0.021
Country × Sex	0.994	1.087	9.000	1,577.000	0.369	0.006

1. Understanding number as a notion representing quantity, utterance of entity in various ways
2. Numerical skills
3. Working with characters (symbols)
4. Orientation and working with table
5. Graphical perception
6. Working with diagrams
7. Knowledge and working with planar geometric shapes
8. Spatial imagination
9. Functions as a relation between values
10. Correctness of logical reasoning

The way of selecting mathematical competencies enabled possibility to create particular mathematic tasks for testing purposes for each class. Difference between each class were determined the number of testing tasks. Frame of mathematic task was based on national curriculum. Presented tasks were consulted and subsequently created by methodologists of mathematics at the Department of Mathematic and Information Science, by methodologists Methodical Centre for teacher of basic and secondary schools. Each task was reviewed by two independent mathematic experts from the Slovak Academy of Science. Number of prepared task was higher than the number of tasks included in tests. The fact that testing tasks were verified by the sample of 100 students of basic and secondary schools was the reason that less tasks were incorporated into the real experiment. The goal of verification was to find out items clearly and exactly uttered, stylistically correct and did not use too simple or too difficult tasks. We considered tasks too simple as a tasks which solution were succeeded for more than 80 % and too difficult tasks as a tasks which solution were succeeded less than 20. We marked such tasks as suspicious tasks and tasks were discarded. Duration of test was 45 min in each class. We used chronoscope to inform student on the expiration of time in every testing subject. Each test was automatically saved and closed by the expiration of time.

Research Results

The current testing process run by electronic way through the Internet. Pupils filled testing tasks on math (as well as natural language, foreign language and natural science basis). Electronic testing allows simple and faster assessment and analyses of the results and immediately processes it up to final percentile.

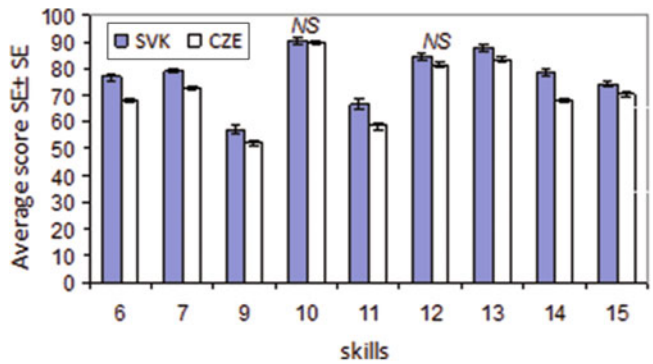

Fig. 1 Particular skill by Slovak and Czech pupils

Results of Third Class of Primary Schools

Two-factor MANOVA was used for testing of difference in mathematic skills between pupils in the Slovak Republic and the Czech Republic, and between boys and girls. Table 1 shows significant difference between Slovak pupils and Czech pupils as well as boys and girls. We emphasize that difference between boys and girls were low and explained only 2.1 % of results variability (Table 1).

Figure 1 that shows that difference between Slovak pupils and Czech pupils are consistent and pupils in the Slovak Republic reached higher scores in most of skills. Except the skills No. 10 and 12 pupils of both countries got over test with the same scores.

Getting over the particular skills by Slovak pupils ($n = 485$) and Czech pupils ($n = 1{,}104$). Considering either countries each unlabeled difference are significant at $p < 0.05$. NS labeled difference are not significant (Fig. 1).

Skill 6—Understanding the concept of expressing a number as the quantity, write a whole variety of ways; Skill 7—*Numerical skills*; Skill 8—*Working with the characters (symbols) (data not provide*d); Skill 9—*Orientation and work with the table*; Skill 10—*Graphical perception*; Skill 11—*Working with graphs*; Skill 12—*Knowledge of and work with plane geometric figures* Skill 13—*Spatial Imagination*; Skill 14—*as a function of the relationship between variables*; Skill 15—*logical correctness account*.

Boys got over particular skills better than girls in four of nine skills. Other skills had not significant difference (Fig. 2).

Difference between boys ($n = 774$) and girls ($n = 815$) in particular skills. Each unlabeled difference are significant at $p < 0.05$. NS labeled difference between boys and girls are not significant (Fig. 2).

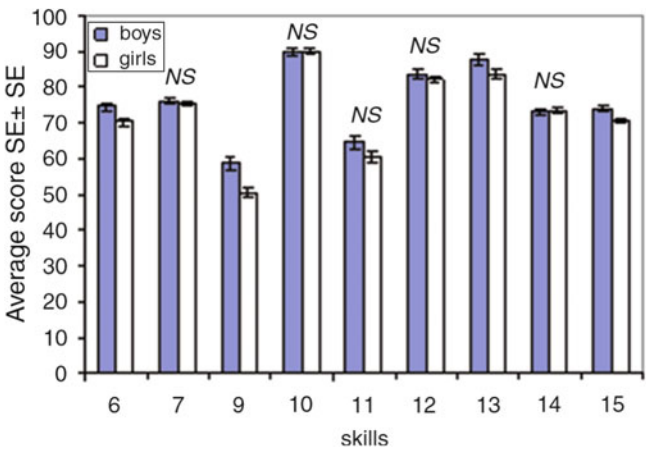

Fig. 2 Difference in particular between boys and girls

Table 2 Correlations between particular skills (for each value at $p < 0.001$)

	7	9	10	11	12	13	14	15
6	0.49	0.57	0.22	0.33	0.20	0.16	0.42	0.49
7		0.57	0.42	0.45	0.41	0.39	0.96	0.71
9			0.26	0.31	0.27	0.30	0.50	0.65
10				0.25	0.32	0.25	0.37	0.65
11					0.20	0.19	0.36	0.59
12						0.47	0.41	0.47
13							0.37	0.40
14								0.60

Table 2 shows that particular skill correlations were statistically significant and correlation range varied from low values ($r = 0.2$) over middle strength values ($r = 0.2$–0.5) up to high values ($r > 0.5$).

Results of Fifth Class of Primary Schools

As it is showed in Table 3 difference between Slovak pupils and Czech pupils were statistically significant. As in previous case difference were caused due to large sample of respondents and the final variability of results was entirely low (Table 3).

As we point out low values of η^2 difference of either countries were less better for Slovak pupils.

Getting over particular skills between Slovak pupils ($n = 600$) and Czech pupils ($n = 1.215$). Each unlabeled difference are significant at $p < 0.05$. NS labeled difference of both countries are not significant (Fig. 3).

Skill 36—*Understanding the concept of numbers as indicating the quantity, write a whole variety of ways* Skill 37—*Numerical skills*; Skill 38—*Working with the characters (symbols)*; Skill 39—*Orientation and work with the table*; Skill 40—*Graphical perception*; Skill 41—*Working with the graph (data not provided)*; Skill 42—*Knowledge of and work with plane geometric figures*; Skill 43—*Spatial Imagination*; Skill 44—*as a function of the relationship between variables*; Skill 45—*logical correctness account*.

Difference between boys and girls getting over the skills were ambiguous, as it is evidenced by the low value of η^2.

Difference between boys ($n = 874$) and girls ($n = 941$) in particular skills (Fig. 4).

Table 4 shows that correlations between particular skills were statistically significant and correlation range varied from low values ($r = 0.2$) over middle strength values ($r = 0.2$–0.5) up to high values ($r > 0.5$).

Results of Seventh Class of Primary School

Two-factor MANOVA confirmed difference in average score in particular skills between Slovak pupils and Czech pupils in mat as well as difference between boys and girls. Explained final variability (η^2) was entirely low as it concerns the difference between boys and girls (Table 5).

Figure 5 shows that difference between Slovak pupils and Czech pupils were very ambiguous. There were score in skills No. 69, 76, 77 better for Slovak pupils and score in skills No. 70, 73 better for Czech pupils. Difference of other skills were not statistically significant. Low value of η^2 suggests that difference between Slovak pupils and Czech pupils were negligible.

Getting over the particular skills by Slovak pupils ($n = 472$) and Czech pupils ($n = 1{,}436$). Each unlabeled difference are significant at $p < 0.05$. NS labeled difference of both countries are not significant (Fig. 5).

Skill 68—*Understanding the concept of numbers as indicating the quantity, write a whole variety of ways*; Skill 69—*Numerical skills*; Skill 70—*Working with the characters (symbols)*; Skill 71—*Orientation and work with the table*; Skill 72—*Graphical perception*; Skill 73—*Working with graphs*; Skill 74—*Knowledge of and work with plane geometric figures*; Skill 75—*Spatial Imagination*; Skill 76—*as a function of the relationship between variables*; Skill 77—*logical correctness account*.

Figure 6 shows that difference between boys and girls were low. In some cases there were better score for boys and in the other cases the difference were negligible at all (Table 4 low value of η^2).

Table 6 shows that correlations between particular skills were statistically significant and correlation range varied from low values ($r < 0.2$) over middle strength values ($r = 0.2$–0.5) up to high values ($r > 0.5$).

Results of First Class in Secondary School

Multi variation analyses method shows that there are no evidences of age influence of pupils in secondary schools in skills from No. 107 up to No. 116. Difference between

Table 3 Difference of skills from no. 36–45 in math

	Wilks' lambda	F	DF effect	DF error	P	η^2
Country	0.945	11.560	9.000	1,803.000	0.000	0.055
Sex	0.984	3.166	9.000	1,803.000	0.001	0.016
Country × Sex	0.996	0.734	9.000	1,803.000	0.678	0.004

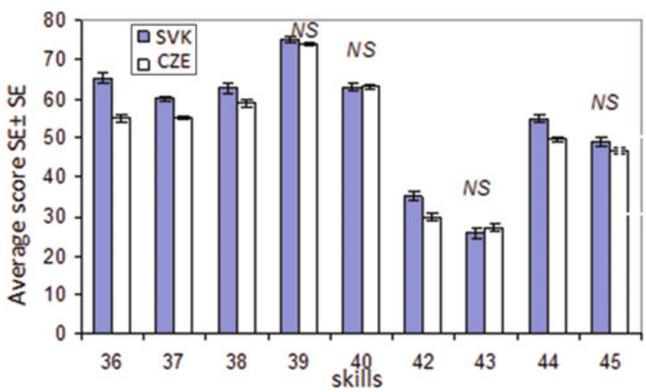

Fig. 3 Particular skill by Slovak and Czech pupils

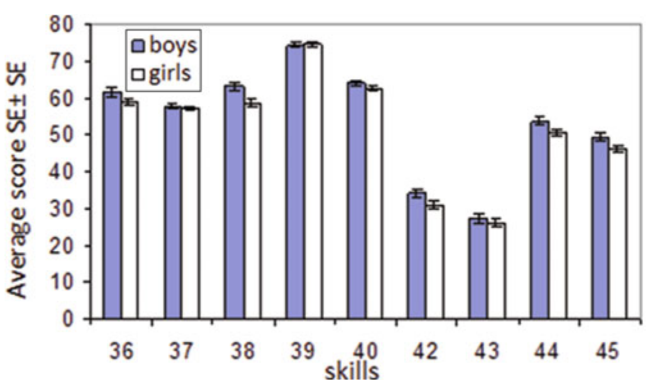

Fig. 4 Difference in particular between boys and girls

Table 4 Correlations between particular skills (each value at $p < 0.001$)

	37	38	39	40	42	43	44	45
36	0.64	0.37	0.42	0.28	0.26	0.20	0.35	0.29
37		0.66	0.70	0.45	0.45	0.35	0.77	0.67
38			0.41	0.25	0.28	0.18	0.85	0.55
39				0.72	0.32	0.34	0.55	0.43
40					0.65	0.33	0.32	0.30
42						0.27	0.53	0.43
43							0.28	0.33
44								0.69

Slovak pupils and Czech pupils as well as difference between boys and girls were statistically significant but influenced by large sample of respondents. Effect size shows (effect size, η^2) that difference were explained in less than 5 % of whole variability of results (Table 7).

Figure 7 shows that difference between Slovak and Czech pupils were negligible, although better for Slovak pupils in some skills.

Getting over the particular skills of Slovak pupils ($n = 414$) and Czech pupils ($n = 327$). Unlabeled difference were not significant. Difference labeled with asterisks are statistically significant at ($*p < 0.05$, $** p < 0.01$) value (Fig. 7).

Skill 107—*Understanding the concept of expressing a number as the quantity, write a whole variety of ways;* Skill 108—*Numerical skills*; Skill 109—*Working with characters (symbols)*; Skill 110—*Orientation and work with the table*; Skill 111—*Graphical perception;* Skill 112—*Working with graphs*; Skill 113—*Knowledge of and work with plane geometric figures*; Skill 114—*Spatial Imagination*; Skill 115—*Function and relationship between variables*; Skill 116—Logical correctness account.

Difference between boys and girls are showed in Fig. 8. Generally boys reached slightly higher scores than girls; low value of η^2 suggests that these difference are not important.

Using correlation analyses method we found out that skills No. 112 did not correlate (or had weak correlation) with other skills (Table 8). In the most of cases were low values of correlation ($r < 0.2$) or medium strong ($r = 0.2$–0.5).

Correlations between particular skills. Unlabeled correlation coefficients are significant at $p < 0.05$. Bold coefficients are not statistically significant (Table 8).

Discussion

Based on the results, we can conclude that the level of skills tested in primary and secondary schools depends on the year.

The difference in skill was tested in third grade primary school pupils, as between boys and girls. We point out that the differences were very small.

Table 5 Difference in skills no. 68–77 in math

	Wilks' lambda	F	DF effect	DF error	P	η^2
Country	0.917	17.223	10.000	1,895.000	0.000	0.083
Sex	0.980	3.861	10.000	1,895.000	0.000	0.020
Country × Sex	0.992	1.527	10.000	1,895.000	0.124	0.008

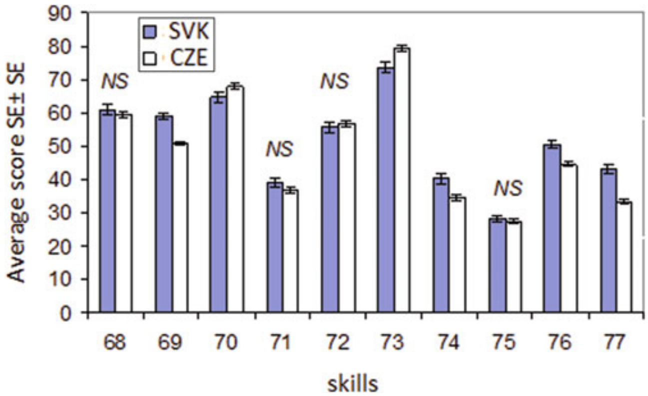

Fig. 5 Getting over the particular skills by Slovak pupils and Czech pupils

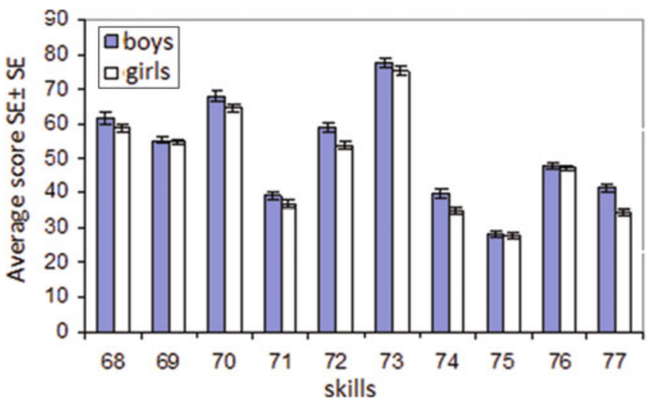

Fig. 6 Difference in particular skills between boys (n = 908) and girls (n = 1,000)

Table 6 Correlations between particular skills (each value at $p < 0.001$)

	69	70	71	72	73	74	75	76	77
68	0.22	0.22	0.40	0.13	0.13	0.16	0.16	0.23	0.24
69		0.41	0.69	0.42	0.42	0.65	0.40	0.90	0.61
70			0.34	0.33	0.91	0.36	0.31	0.43	0.40
71				0.33	0.31	0.66	0.44	0.76	0.51
72					0.34	0.60	0.4505	0.48	0.58
73						0.35	0.29	0.43	0.29
74							0.38	0.77	0.60
75								0.42	0.33
76									0.60

The results achieved by pupils fifth grade of primary schools on results were significant. The reason why this was so, the sample size of students, because the total variability was very low (see Table 3).

For students seventh year, we can also see the differences between countries and between boys and girls. Reliability in the context of gender differences was also very low, boys achieve higher scores than girls in all tested skills.

For high school students 0ultivariátna analysis of covariance showed no effect of age on skills with 116 secondary school students. The differences associated with students from Slovakia and the Czech Republic, and although gender differences were statistically significant, but again, however, affected by large sample. Calculation of the "size of force" (effect size, η^2) showed that differences explain only less than 5 % of the total variability of the results (Tables 7 and 8).

Conclusion

Realized research has shown that computer based testing is an effective tool not only testing, but it can also contribute to increasing the digital literacy of pupils, students and teachers. The software has been created for the purpose of testing (since the results are anonymous) may be primary and secondary school teachers and an excellent indicator of the cognitive level of pupils and students in comparison with other schools. The aim was to determine whether there are regional differences and gender differences in mathematical competence. At the same time develop and test a suitable tool to effectively detect these differences. The results showed that both targets were fulfilled. The results are currently being further analyzed in the context of educational programs and policies, along with cross-curricular links with a view to identifying the causes of the existing differences.

The main goal of the research was to identify cognitive levels of pupils of selected classes at primary secondary schools and high schools. The findings were developed guidance materials for specific classes and selected subjects and use them to promote the development of selected competencies in this case, subject of mathematics. The main goal and the reason why we have tested of pupils from the border of Slovakia and the Czech Republic was

Table 7 Difference in skills from no. 107 up to no. 116 in math

	Wilks' lambda	F	DF effect	DF error	P	η^2
Age	0.984	1.171	10.000	727.000	0.307	0.016
Country	0.951	3.781	10.000	727.000	0.000	0.049
Sex	0.965	2.620	10.000	727.000	0.004	0.035
Country × Sex	0.976	1.776	10.000	727.000	0.061	0.024

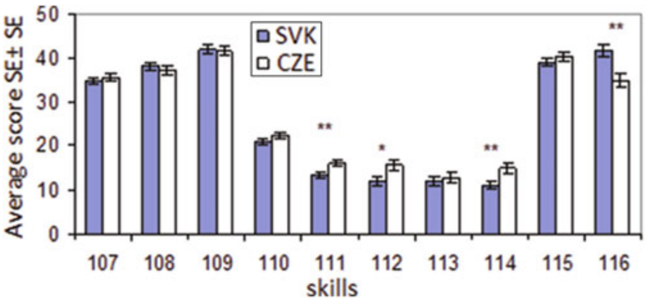

Fig. 7 Mastering the skills of students from SR and the Czech Republic

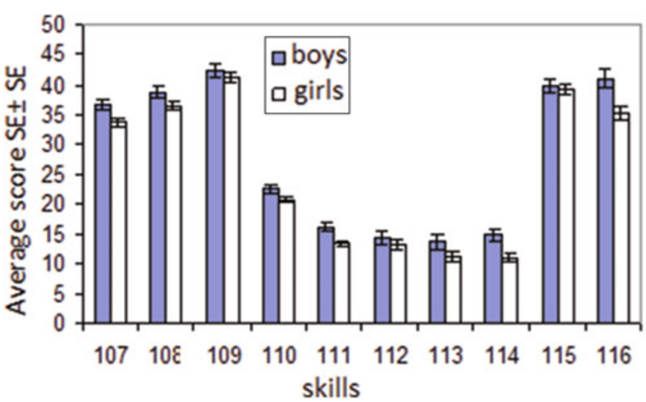

Fig. 8 Difference in particular between boys and girls

Table 8 Correlations between particular skills (each value at $p < 0.001$)

	108	109	110	111	112	113	114	115	116
107	0.67	0.62	0.79	0.15	**−0.07**	0.10	0.12	0.46	0.16
108		0.91	0.48	0.17	**−0.09**	0.06	0.08	0.80	0.31
109			0.31	0.10	**−0.08**	**0.04**	**0.03**	0.79	0.19
110				0.42	**0.06**	0.31	0.35	0.43	0.27
111					0.48	0.34	0.75	0.27	0.45
112						0.15	0.23	0.22	0.11
113							0.67	0.12	0.20
114								0.14	0.18
115									0.30

the fact that both countries have the same education policy over existing one State. We interested how the change education policies both countries for the last 20 years after the separate.

Principal investigator presented plans to continue research in the next phase, which will provide software testing countrywide level for all primary and secondary schools in the Czech Republic and Slovakia. Expected (achieved) results will be carefully analyzed and then compared and presented at the individual countries, subjects and between countries themselves. Currently developing branch of research itself focused on virtual field trips.

Acknowledgment The publication of this paper was supported by grant KEGA 119-005TVU-4/2010.

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Determination of Optimal Hyper- and Multispectral Image Channels by Spectral Fractal Structure

Veronika Kozma-Bognár and József Berke

Abstract

Multiband aerial mapping technology—for the high spectral and high spatial resolution images—also the phenomenal traditional aerial mapping techniques, which are more reliable, compared to data obtained during the foundation stages of the process. Over the last decade, aircraft data recording technology has developed considerably due to its applications in the field of research and has become an increasingly central theme of multiband and high spatial resolution integrated processing. This has a significant impact on assessment results. Using practical examples, the author's show that a properly selected spectral fractal structure based on data reduction and data selection procedures, significantly contributes to the hyper- and multispectral data cube optimum exploitation of additional information.

Keywords

Optimal bands • Hyperspectral image • Spectral fractal dimension • Spectral data reduction • Particulates pollution

Introduction

The twenty-first century characterized the great extent of the affects of the rapidly growing developments in information technology, in the field of remote sensing science. In recent years, the development of remote sensing technologies has played a vitally more important role in a range of multispectral and high geometric resolution images. The multiband and high resolution aerial and satellite images of active applications and laser measurement technologies open up new perspectives on the object surface and the amount of accurate data collected. Presently, following a long delay, the technical development of sensor processing methods and applications, is now justified to clarify existing procedures, and new analytical methods. Despite the fact that the world has been introduced to several imaging and multiband integrated programs [14], in order to support the processing of images, the range of these remains quite limited. Much GIS software has been developed, for example the adaptation procedures for the main methods of hyperspectral image processing for existing multispectral shots. Hyper- and multispectral technology resulting from disparities (e.g. difference of the channel bandwidth, the geometric resolution), raises questions as to the accuracy of these methods. The procedures selected depend on its order, the software use, experience of the person doing the processing and the impact on the multiband images of the final outcomes.

Data processing of the data cube, which make up hundreds of spectral channels for part of preprocessing selection, which contain the information necessary for the implementation of the tasks. The channels of data cube can be charged with noise and/or correlated with each other [5, 17]. Band selection methods are used to filter redundant

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_34,

data [15] such as the common essence: principal component analysis [12], minimum noise fraction [7, 12], lambda-lambda R^2 model [13], stepwise discriminant analysis [16], derivative greenness vegetation indices [6]. The preprocessing, within dimension reduction methods, greatly affects the outcome of the evaluation, because inadequate preprocessing may be excluded from a band that has useful informations for our investigation.

During research and goal-oriented studies, we aimed to develop a method that allows for multiband aircraft images, which selects maximum information to be considered in the production of optimal shots. Another consideration is that when different methods are used together sensors produced high spectral resolution images and high spatial resolution data, which is workable and useable.

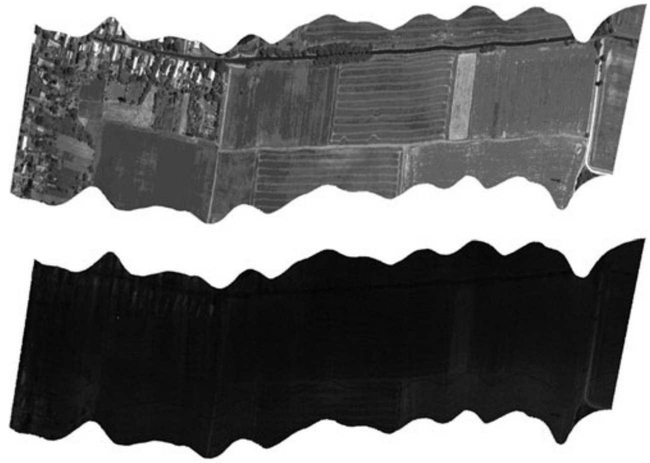

Fig. 1 Noise-free (254th band, *upper*) and noise (273rd band, *bottom*) AISA Dual Image Layer from Várvölgy test area, 06/19/2007

Materials and Methods

Research Sites

The research areas of the two samples were analyzed from recordings. Hyperspectral research took place in the rural Bakony landscape, which is located on the outskirts of Várvölgy (Hungary). The test areas [9] (the highest point coordinates: N: 46°51′20.76″, E: 17°18′06.53″, H: 247 m), were chosen which are mostly used for agricultural land use. The test areas also include easily identified target and other terrestrial objects (forest belt, driveway, dirt road), which later served as points of reference during this study (Fig. 1). The field data collection determined the number of categories and a total of eight categories are reported in the survey. The entire test area, situated in natural and artificial formations, was assessed, and data collection was carried out on the state of the plant population. Immediately following data collection, the research areas are finally reviewed and records are compiled to define the types of objects involved. The following categories have been set: corn, triticale, wheat, sunflower, uncultivated land, forests, driveway (asphalt), a dirt road.

Multispectral research was carried out 2 km from Keszthely (Hungary) at the Agrometeorological Research Station test area, where the corn plot experiments involving traffic originating pollution took place [10]. Located north of the station (the center of the test area N: 46°44′08.55″, E: 17°14′19.76″, H:114 m) a test area comprising of six plots (10 m × 10 m/plot) was established.

The motor vehicle emissions and negative environmental effects of chemicals that cause physiological tests to two characteristics of the contaminant were selected: carbon black, and cadmium. Accordingly, multispectral collection was evaluated for the following determined object types:

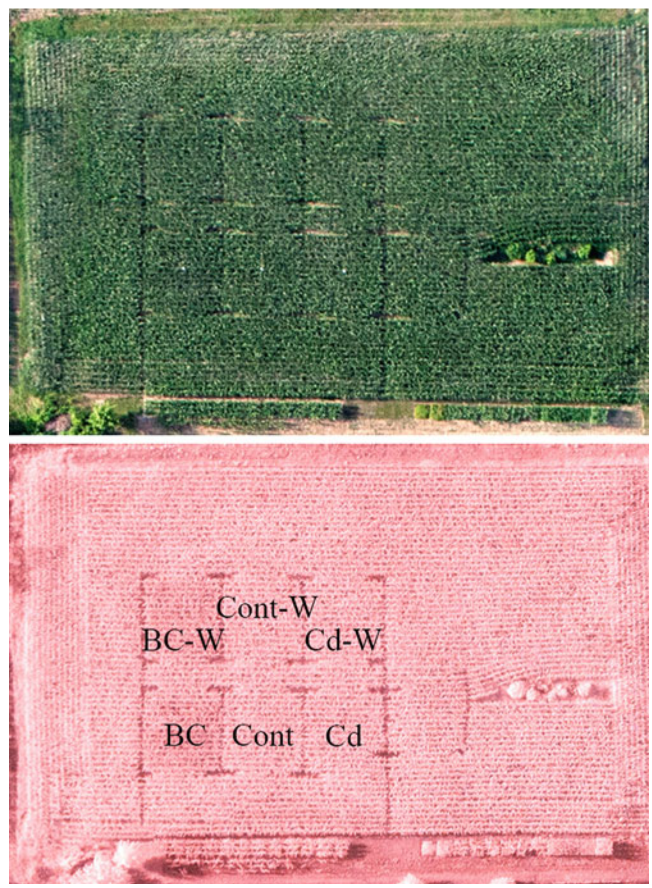

Fig. 2 Visible range (*upper*) and near infrared (*bottom*) image from test area of Keszthely, 06/21/2012

BC = Black Carbon polluted, BC-W = Black Carbon polluted and irrigated, Cont = Control, Cont-W = Control irrigated, Cd = Cadmium polluted, Cd-W = Cadmium polluted and irrigated (Fig. 2).

Table 1 Main parameters of data collection with the help of air-shot

	Visible data (VIS)	Near infrared data (NIR)	Hyperspectral data
Type of sensor	Canon 30D	Canon 30DIR	AISA Dual
Height of flight	400 m	400 m	1,200 m
Spectral band	400–700 nm	720–1,150 nm	400–2,450 nm (498 bands)
Geometrical resolution	0.1 m	0.1 m	1.0 m
Data recording	14 bit/pixel	14 bit/pixel	14 bit/pixel

The realization of an accurate study of the possible preprocessing for eliminating problems resulted in images of the total area of each plot being used as a criterion for selection, which were then analyzed.

Applied Tools

During the study Hungarian hyperspectral AISA Dual hyperspectral sensor aerial images were analysed. The AISA Dual hyperspectral sensor system is one of the most important in the European Union developed by the Finnish SPECIM Spectral Imaging Ltd. The family members of AISA camera combine the AISA Eagle and Hawk sensors. The container has been secured by the coordination of the VNIR spectral range in order to collect data from up to 498 spectral bands. The AISA Dual System is a compact, low-cost, aircraft-mounted, high-performance and highly operational characteristic of the imaging system. The AISA stable operation system provides us with high spectral and relatively high (max. 1.0 m) spatial resolution aerial images, which provide us with enough information for our Várvölgy field test study. The sample area covered was smaller in Keszthely due to the appropriate required level of assessment for recording the results of higher spatial resolution. The multispectral airborne imaging test area considerably surpassed the resolution of 1 m below the field (7–30 cm^2/pixel). The high resolution multispectral images for field production data provided by the sensors used in digital lines in the visible (VIS: 0.4–0.7 mm) range and the near infrared (NIR: 0.7–1.15 mm). Major collection tools were used for mapping the parameters in Table 1.

Spectral Fractal Structure

The starting point of the hyper- and multispectral images, using the characteristics of the data reference, began when the different plant populations spectral fractal dimension measurements were taken. The measurement program developed by the SFD Information Technology Ltd [1]. Was considered optimal for spectral bands used to select and validate the fractal dimension (SFD) values. Reviews of the images containing the tested crop areas were analyzed, and those values only measured SFD.

The SFD is a general fractional dimension [11] derived from the structure of the processing, which is a novel application of fractals. The spatial dimensional structure of the SFD outside of the spectral bands is also suitable for measuring the color structure [1, 4] and provides sufficient information to colors, shades and other fractal properties as well. Calculating the values of the SFD (two or more band images), the defined fractal dimension is applied to the measured data as a function (the total number of boxes valued spectral function of the spectral box) simple mathematical averages are calculated as follows [2]:

$$SFD_{measured} = \frac{n \times \sum_{j=1}^{S-1} \frac{\log(BM_j)}{\log(BT_j)}}{S-1} \quad (1)$$

where,
n—the number of image layers or image channels
S—the spectral resolution (in bits)
BM_j—valued spectral pixel boxes containing j number of bits
BT_j—all possible spectral boxes for the number of j-bits

The possible number of boxes spectral j bits is calculated as follows:

$$BT_j = \left(2^S\right)^n \quad (2)$$

Since the formula (1) metric [3], the evaluations of both hyper- and multispectral images can be used for exact measurements.

Determination of the Optimal Conditions for SFD-Based Studies

Hyperspectral imaging system's service data could be highly noisy and redundant. For this reason data analysis, which considers noisy and redundancy as bands, we search the optimal bands, which adequately represent all of the image information. The Várvölgy test area, which has 359 available channels of data cubes in some bands, was observed as

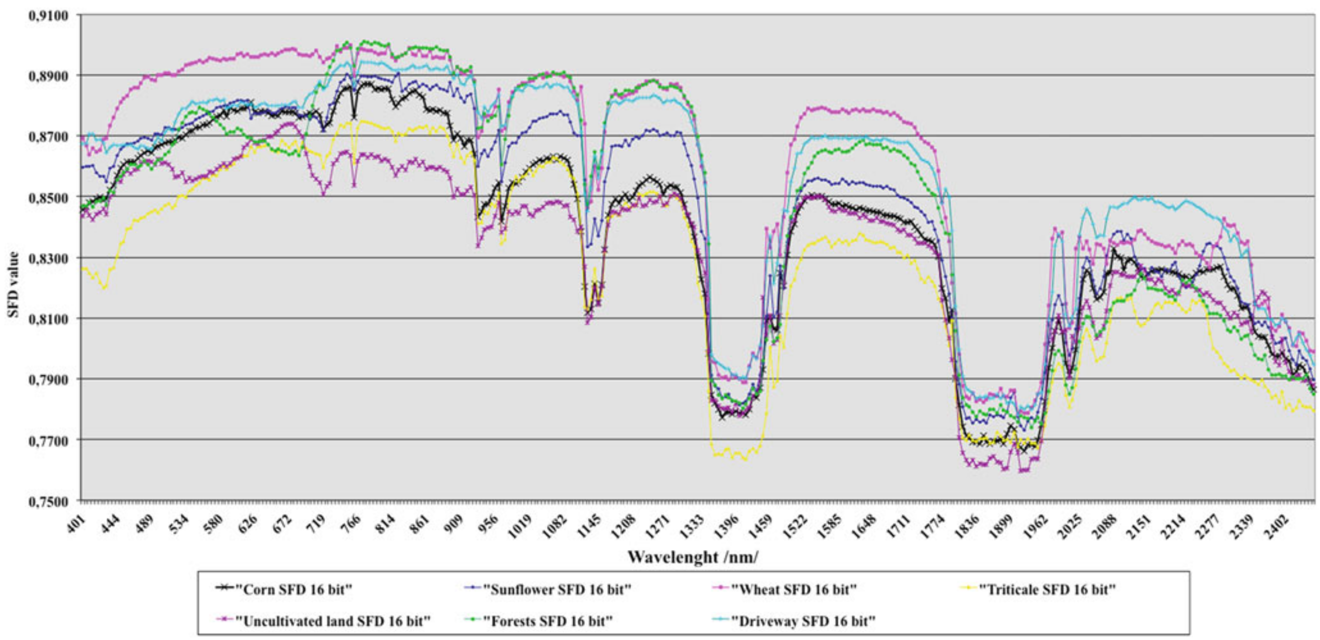

Fig. 3 16 bits SFD fingerprints of corn, sunflower, wheat, triticale, uncultivated areas, forests and driveway

having a strong correlation with literature, which offers different data reduction procedures, such as principal component analysis, and the correlation between the individual channels, or energy minimization. Many of these procedures do not contain the actual image data reduction, and can only be described as pieces of information about the probability of actual data on a number of independent bands (PCA-based methods). However, there is not always enough information available from the bands, or the information provided highly depends on the input data (e.g. depend on the rate of noisy bands and of their weight). In order to overcome these problems, a data processing method, which is not or is less sensitive to the input data procedure, should be used. Using this procedure, we have achieved results in SFD based structural analysis, using the correct application of noise results [10]. This task is also proposed to serve as an additional solution.

The first step is testing the hyperspectral image created by the SFD based fingerprint crops, which represents the channel or SFD values versus wavelength (Fig. 3), [8].

The SFD plant cultures per band and their measured values are sorted in descending order according to the channel numbers. Five plants of these five columns are sorted in the order in which adjacent value differences were formed, and these difference values were added and titled: "organized patterns of differences in the amount of SFD". Then the resulting curve approached the local maximum value of channel numbers, which are the channels for optimal recording of a particular crop (Fig. 4).

Figure 4 demonstrates the top 21 local places with a maximum of five plants of maximum position found for the five following crops (corn, wheat, triticale, sunflower, uncultivated areas), which are the following: 2, 26, 49, 55, 62, 78, 83, 90, 98, 114, 122, 138, 166, 201, 215, 272, 285, 293, 301, 327, 350. The hyperspectral images of adjacent channels are usually from the same correlated sources of information, therefore, there was a condition placed on the obtained local maximum that they are considered not to fall within a range of at least two bands. We believe this series uses the most appropriate channels for the further phases of evaluation (e.g. classification). As a further alternative, aspects of the 359 channels are selected six channels, in which some are named as the minimum optimal channels. The SFD fingerprints based on the following six channels were considered to be optimal for the outermost bands between local maximum ratings: 65, 71, 128, 167, 243, and 288. We calculated the standard deviation amounts with the aim of more adjacent channels of the same values and, the standard deviation of the lowest channel for selection.

Based on the above channels, for the purposes of ascertaining the optimal information content of the resulting bands, the area used as input for the spectral angle mapper method of carrying out classification was considered. In addition, other method to reduce the number of data channels was measured and determined by comparative analyzes and were carried out based on the accuracy of results. Giving the optimal channel selection procedures for comparing the different methods of data as input for completion of the surface identification categories. Subsequently these were evaluated to reduce the number of dimensions which best describes the result of the processing of our test crop.

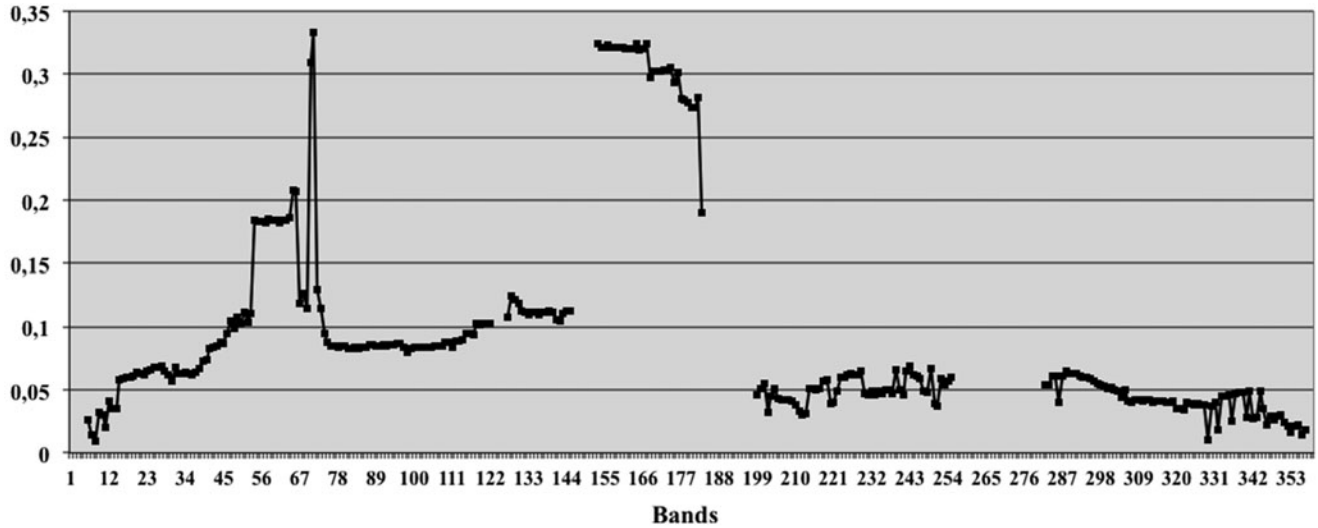

Fig. 4 Arranged in increasing order of the sum of the difference between the SFD

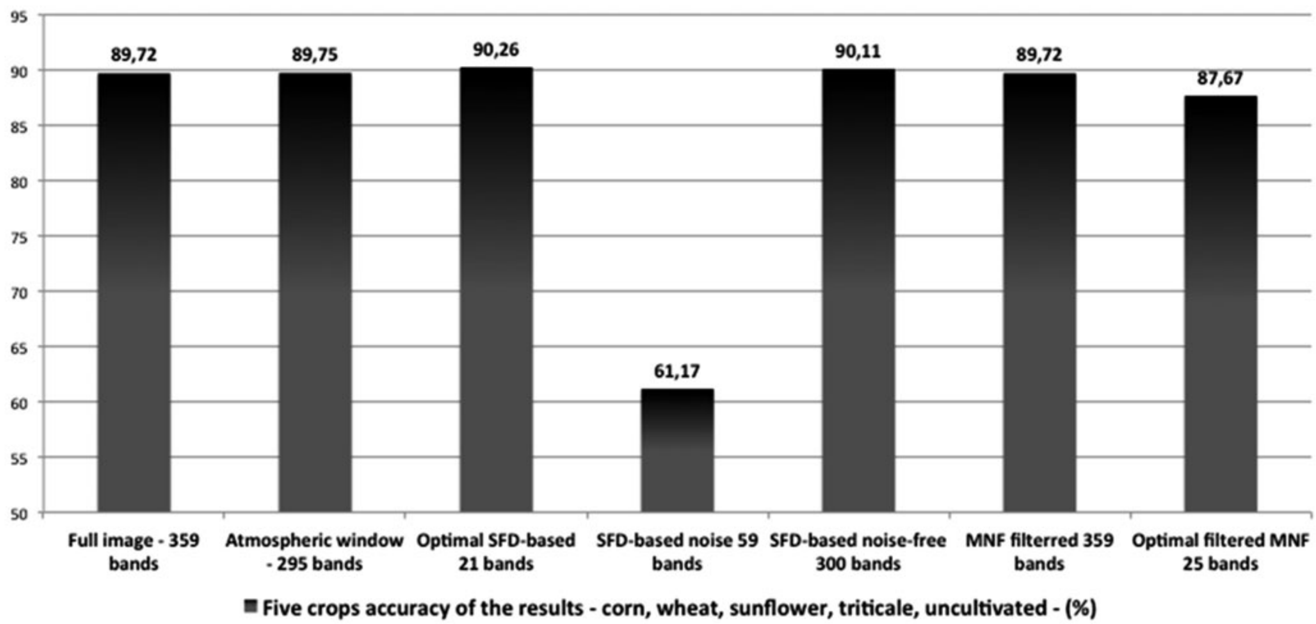

Fig. 5 Procedures to reduce the total number of dimensions—the result of plant cultures

The classified images were taken and the results of the error matrix were calculated with the accuracy of the results for each of the crops (Fig. 5), and the average of the five crops, i.e., seven methods were prepared using input data series (full image—359 bands; atmospheric window-based bands—295 bands; optimal SFD-based minimal bands—6 bands; SFD-based noise-free bands—300 bands; SFD-based noise bands—59 bands; optimal filtered MNF bands—25 bands, filtered MNF bands full image—359 bands). The obtained results clearly show that the SFD value-based methods for optimal bands selected crops combined results of the highest accuracy. We note that in practice, the most accepted and used noise reduction method (MNF = Minimum Noise Fraction) to carry out the image after the input of the hit accuracy was the same as the accuracy of the unfiltered image results. This can be explained by the effect of the MNF noise reduction AISA Dual image sensor, we recognized some visible band, and however, the accuracy of the results was invariant.

We have developed the channel selection procedure based on the SFD values of the multispectral images used to optimize the selection of images. In investigation, the

Table 2 Maximum SFD values of the multispectral images

	Visible SFD values 3 bands	Near Infrared SFD values 3 bands
Track 1	2.1361	1.9418
Track 2	2.1416	1.9187
Track 3	2.1398	1.9400
Track 4	2.1328	1.9215
Track 5	2.1273	1.8406
Average	2.1355	1.9125

SFD values were deduced from the size of the actual information content of images. Airborne imaging of one-one workflow (e.g. flight track) recording usually occurs in the Keszthely sample area where they were looking to provide the best and most reliable information for the object-finding study.

The multispectral images of the preprocessing, post processing only recorded SFD maximum purchasing values per sensor and per flight (Table 2), as further investigations of these images gave the most reliable results (hit accuracy as well as other measured parameters and correlation studies).

Comparision of Hyperspectral Data Selection Procedures

In the scope of our research different classification methods for analyzing hyperspectral images were selected. We have chosen the optimal minimum and maximum bands based on spectral fractal structures for optimal selection to discuss the effectiveness and the accuracy of the results of each classification method.

We investigated five supervised classification methods, the basic aim of the selection was to investigate methods that are primarily examining the development of multispectral images, and however the development of a unique hyperspectral data classification method is also present in the comparison. An additional consideration is that the most commonly used hyperspectral data processing software methods are able to be studied, since the users, especially professionals, primarily engage with this form. The above concerns the following five metrics based on the classification methods selected: Parallelepiped (PA), Minimum Distance (MD), Mahalanobis (MA), Maximum Likelihood (ML), Spectral Angle Mapper (SAM). One independent samples (region of interest = ROI) was selected on each of the nine tested areas by the input parameters of the classification. The five classes consist of nine samples, whereas in four cases (areas 1 and 3 corn, areas 2 and 5 triticale, areas 4 and 6 wheat, area 7 uncultivated area, areas 8 and 10 sunflower) two plots grow the same crop. We have also added a

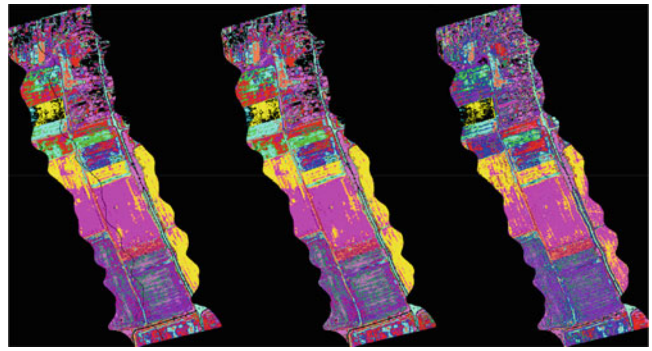

Fig. 6 Spectral Angle Mapper image metrics based on graded results (based on full image, noise-free channels of SFD and six optimal channels)

further three samples (forest, asphalt driveway, dirt road), which were not the subject of our study, but were found between the fields in the former nine samples.

The aforementioned 6 minimum and 21 maximum optimal channels were definded by SFD spectrum curves. In addition to the studies have been investigating the full 359 channels of recording and the selected bands without noise on the basis of the SFD.

The accuracy of the results was measured on the classified images (Fig. 6). Within each ROI, the numbers of pixels correctly classified were determined by the ROI intensity values. The accuracy of the results in percentage was calculated from the number of correctly classified pixels divided by the total ROI, and then multiplied by one hundred. The average price for the five crops selected images classification processing are based on the accuracy of results summarized in Table 3.

The result analysis clearly shows that the classification of the proposed channels by the SFD fingerprints (without noise, the minimum and maximum optimal channels), based on the choice of any metrics for corn, wheat, uncultivated land and sunflower crops, allowed greater accuracy results than the classification of the 359 channels. In the case of triticale classification of four metrics (MA, ML, MD and SAM) obtained similar results. In conclusion, the amount of PA gave the least accuracy (69.91 %) among the five classification procedures, which is explained by the fact that the PA does not develop specifically classified hyperspectral images. The classifications of the ML clearly performed best (97.61 %), which is consistent with the results of most of the multispectral image processing methods obtained from literature [5, 6]. However we did not expect such accuracy as a consequence of considerable noise of hyperspectral images. Interestingly, the highest accurate individual aggregate results were obtained from the Mahalanobis classification for noise-free image (98.61 %). Another important finding, following the removal of the noisy bands by the SFD spectrum curves, the accuracy of

Table 3 Average accuracy of results in the selected classification methods

Average accuracy of results					
Type of supervised classification	Full image (359 bands)	SFD-based noise-free (300 bands)	Optimal SFD-based minimal (6 bands)	Optimal SFD-based (21 bands)	SUM
Mahalanobis	96.21	98.61	86.09	92.74	93.41
Maximum likelihood	98.16	98.49	96.08	97.71	97.61
SAM	75.91	76.66	75.23	74.40	75.55
Parallelepiped	65.35	73.45	68.00	72.84	69.91
Minimum distance	80.61	80.56	82.68	79.46	80.83
Average	83.40	85.56	81.61	83.43	

the 300 channels classification was measured 2 % higher (2.16 %) than the classification of the 359 channels.

The result is superior from the aspect that we obtained, in this case, a significant increase in the high accuracy of the results. The 21 bands classification demonstrated almost the same (slightly better) as the 359 bands, which in our case is important because 21 bands based classification has been running for a significantly shorter time than the (computing capacity) 359 bands based classification. The 6 bands classification accuracy of the result was just below (1.79 %) in the overall accuracy of 359 bands. Knowing that the running time has an almost two fold magnitude difference, this is an excellent result for images classifications with high-performance computing workloads.

Conclusion

In the hyperspectral image data cube can accurately identify surface objects with the use of the SFD curves. The bands of the local maximum of the SFD fingerprints accurately representing the total information content of the image data. In some cases these bands represent more reliable data selection than other mathematical methods based on the eigenvalue calculation. The image classification of noise-free channels which are defined on our SFD spectrum curves, based on the choice of five metrics (PA, MA, ML, SAM and MD) for corn, wheat, uncultivated land and sunflower crops allowed greater accuracy of results than the classification of the entire 359 bands. The classification on the basis of the noise-free, optimal channels which are defined on our SFD spectrum curves, in almost all investigated metrics showed a higher accuracy of the results than the entire image (359 channels) using significantly less computing capacity. In the preprocessing of multispectral images, from the maximum spectral fractal structure selected images provide the most reliable accuracy for the measured results and for the other correlation studies.

Acknowledgment This research was supported by the European Union and the State of Hungary, co-financed by the European Social Fund in the framework of TÁMOP 4.2.4. A/1-11-1-2012-0001 'National Excellence Program'. The multispectral images were carried out partly of a project TÁMOP-4.2.2/B-10/1-2010-0025.

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ICT as a Mean for Enhancing Flexibility and Quality of Mathematical Subjects Teaching

Mária Mišútová and Martin Mišút

Abstract

Some results of educational experiments conducted as a part of long-term research project are described in this paper. Primary goal of the research was to improve the quality and flexibility of mathematical education by implementing of new teaching model with ICT support. The model was designed with an aim to increase flexibility and quality of teaching mathematical subjects at the Faculty of Materials Science and Technology of Slovak University of Technology. Described experiments were oriented onto verifying the proposed teaching model.

Keywords

ICT • Mathematics • Quality of teaching

Introduction

Nowadays, implementation of information and communication technologies to education becomes necessary. ICT enables to create means which support efficiency of contact and of course distance teaching. At the same time ICT develops the ability of independent learning via the interactive teaching and self-testing electronic materials.

The core of our university students' activity is development of their ability to solve problems in engineering effectively. One of basic assumptions for that is to understand mathematical theory and be able to apply it. Students of the Slovak University of Technology gain mathematical knowledge and competences within compulsory courses of mathematics. However, according to our experience, some of students had problem to use mathematical knowledge properly, as well as to improve mathematical abilities by self-study. Most of students reported [1] lack of application knowledge, and support by technology and mathematical software. Moreover a big portion of students were not able to finish mathematics courses and failed to continue study at our university.

To overcome these problems research goals were stated, taking into account that both mathematics curricula and how mathematics is taught need to be re-thought (in accordance with Pierce and Ball [2]). As research showed us, the provision of hardware and software alone is not enough (for example, Bottino and Chiappini [3] make the point that provision of technology alone is not enough to bring change; but the revision of teaching approaches and mathematics curricula is needed as well).

On the base of this assumption a research program for improvement of teaching mathematics was proposed. This program was scheduled for longer period while each period was supported by different grant resources and different research activities. It is possible to express the main goals of new program by questions:

- *How can new curricula be designed to meet the needs and possibilities?*
- *How can the use of computers help the teaching of mathematics?*

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_35,

- *How can attitude of students be improved toward mathematics?*

To solve problems described above a new model of teaching was proposed. This model broadly uses ICT with goal to yield students effective tool for mathematical problems solving that will face during following years of study and praxis. The content of subject was more precisely focused onto applicability of gained mathematical knowledge in following study as well as in praxis. New model made resources or expertise more accessible (e.g. providing online support and resources), and mathematical content is co-mediated through technology. New model changed the ways of solving problems using technology that students must learn, and learning environment was changed, as well. It covers our perceptions of what improved student learning might look like (e.g. more engaged, learning with understanding).

This paper describes results of verifying the didactical efficiency of proposed teaching model with the application of information and communication technologies via pedagogical experiments.

Implementation of Teaching Model

The teaching model [4] was applied in teaching mathematics within the first year of study. Educational process is supported by technology. Students have the package of educational e-materials at their disposal. This package includes:

- educational content (additional interactive teaching materials, e-lectures, e-presentations from lectures);
- application of knowledge (file of key solutions, activating exercises in the form of e-textbook); [5, 6]
- self-evaluation tasks—interactive self-tests [7].

To be successful in subjects mentioned above, student has to be successful within two components creating the evaluation of subjects. Results achieved in the post-test (final), which was aimed to verify the ability to apply the acquired knowledge, are essential for evaluation of subject with the weight of 0.6.

Semester tests result consisting the second part of evaluation with the weight of 0.4. The emphasis during the whole teaching process is put on activity, creativity and self-activity of students. Example of interactive learning material oriented onto effective use of *wxMaxima* software in mathematical analyses and algebra is shown in Figs. 1 and 2.

Research Description

The aim of research was:

- Find out whether the implemented model of education with application of information and communication technologies influenced the results of students in educational test.
- Find out the attitude of students to package of e-study materials, which were the important component of proposed model.

The research was realized during academic year 2011/2012 at the Faculty of Materials Science and Technology of Slovak University of Technology in Trnava. The selective sample consisted of 681 students of the first grade of study of all study programs. More detailed characteristics of the research sample are shown at Figs. 3 and 4.

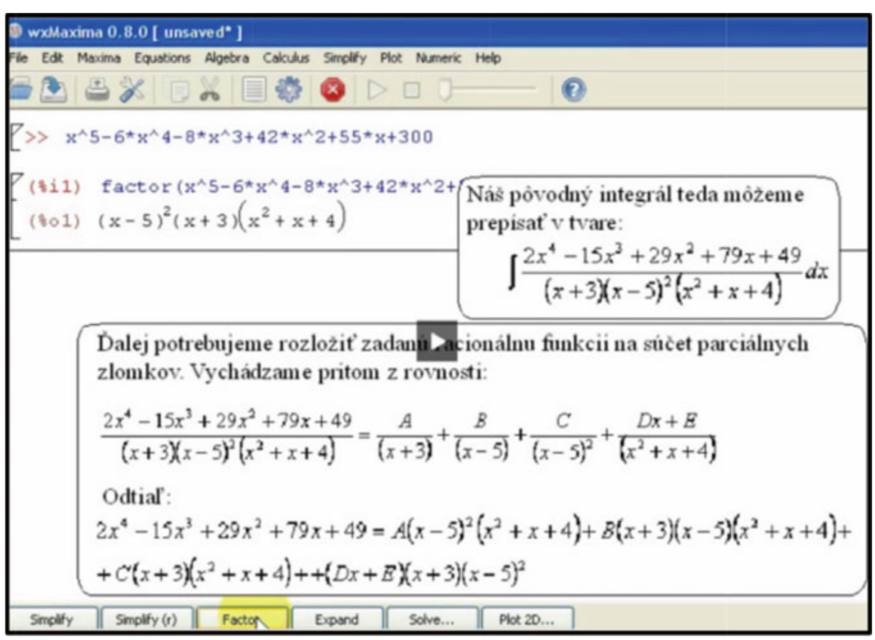

Fig. 1 Illustration of tutorial

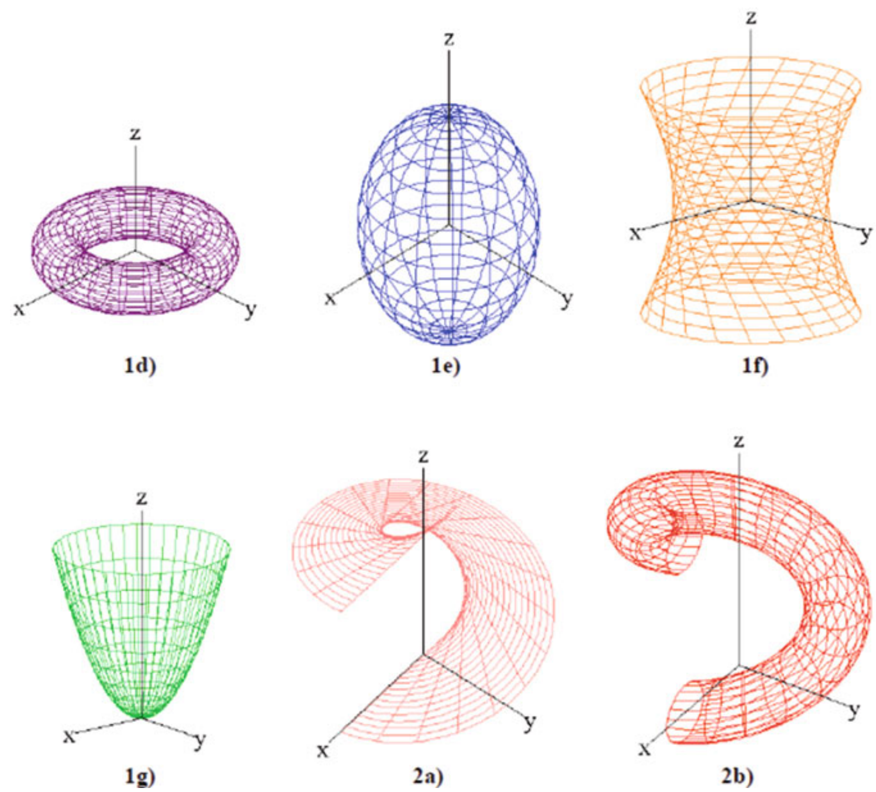

Fig. 2 Example of interactive teaching material from mathematics

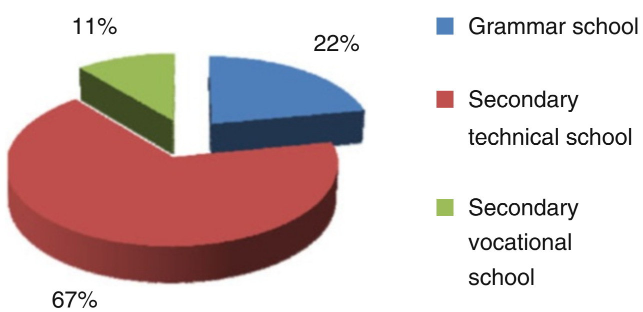

Fig. 3 Kind of secondary school distribution in research sample

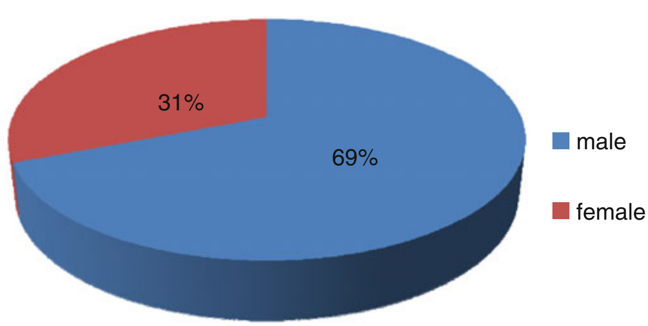

Fig. 4 Percentage of male and female in research sample

Ratio between man and woman was 7:3 as research was realized at engineering faculty. Experimental group consist of 477 students and control group of 204 students respectively. The average score of admission procedure was calculated for each group. Score in admission procedure is calculated on the base of secondary school results (mostly for results in math and physics) as well as other activities connected to study abilities taking into account kind of secondary school. Two-Sample t-Test with equal variances (on the base of two-sample F-Test results, assuming normal distribution) proved that both groups are equivalent (there was not statistically significant difference in average score). Calculated value of test criterion was $t_{stat} = 0.729$ with $\alpha = 0.05$ critical value was $t_{krit} = 1.992$. For given values $|t_{stat}|\langle t_{krit}$ is valid. However, group with lower average score was selected as experimental group, we can conclude that groups were equivalent from students' knowledge and abilities to study.

Students in control group were taught by old method (the new model was not implemented).

The following working hypotheses were stated:

1. Students of experimental group will achieve in educational test higher score in comparison with students from control group.

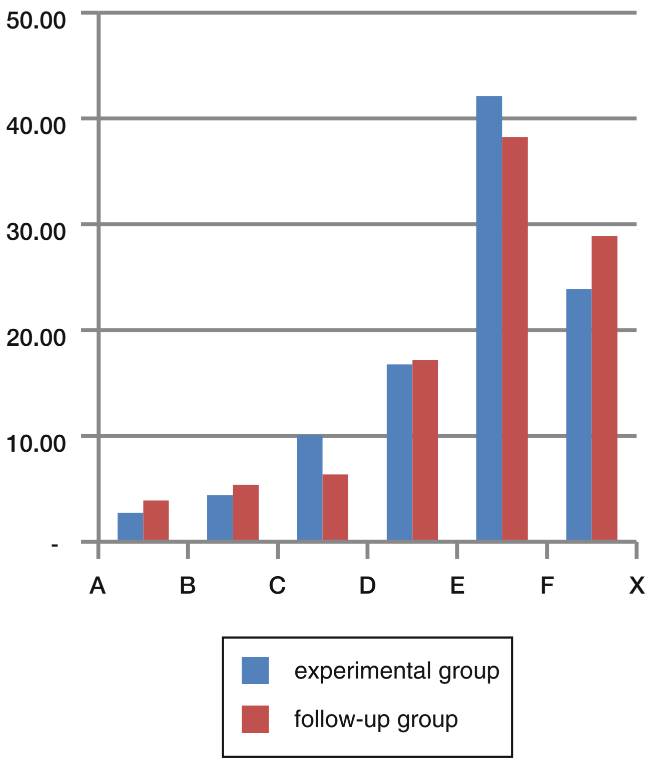

Fig. 5 Graphical illustration of relative successfulness in educational test (grades in %)

2. There will be dominance of students' positive attitude to e-materials and their application in subject study.
   For verification of working hypotheses were used:

- Educational test-oriented to application of knowledge. It included open tasks.
- Questionnaire was compiled on the basis of semantic differential. The attitude to reviewing subjects was measured with the help of several 5-stepped scales from the point of view of selected factors. Scales consisted from two adjectives or verbs. Negative adjectives or verbs got 1 point and words expressing the positive attitude got five points from five stepped scale.
- Statistical methods of elaborating research results—results are elaborated with the help of statistical functions of MS Excel 2000.
- F test for statistical verification of hypotheses

Research Results

Hypothesis 1 assumption that students of experimental group will achieve in educational test higher score in comparison with the students from control group **was confirmed**. It is evident from the graph on the Fig. 5 that students of experimental group achieved in test the higher

Table 1

	F-test			
Group	Mean value	Dispersion	F	F_{krit}
Experimental	2.93	0.59	0.87	0.83
Control (follow-up)	2.98	0.68		

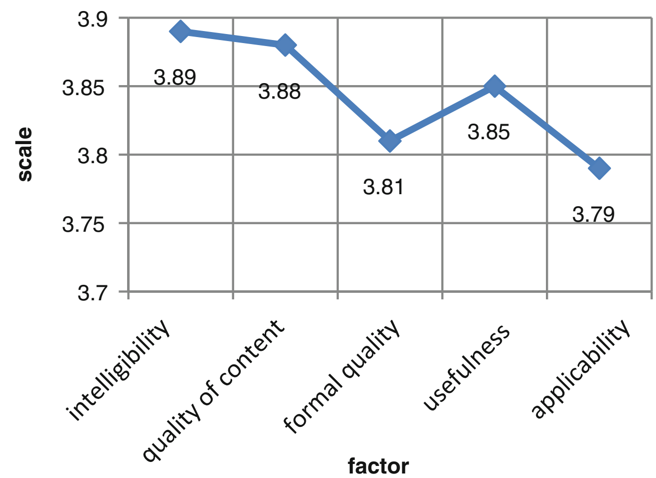

Fig. 6 Semantic profile of e-materials

relative successfulness than students from control group. The difference was statistically significant. There are values of two sample F-test for dispersion, calculated from figures of absolute successfulness in the test. Calculated value of testing criterion F is higher than critical F_{crit}. ($F > F_{crit}$), for given grades of freedom and selected level of significance $\alpha = 0.\,05$ (Table 1).

Hypothesis 2 which supposed that there will be dominance of positive attitudes to e-materials and their use during the study of subject **was confirmed**. There is semantic profile of e-materials on Fig. 6. Factor usefulness expresses the attitude of students to e-materials from the point of help during the subject study and the factor applicability reflects the wish to use analogical materials also during the study of other subjects. The meaning of the other factors is evident.The component of the research was to find out the exploitation extend of individual types of study materials. In the questionnaire interactive study materials, e-lectures, e-textbooks and interactive self-tests were included, as well as notes from lectures and consultation. The authors were surveying the extent of use of individual study materials created by student during the attendance of education. The graph on Fig. 7 shows that students during mathematics study most often use e-lectures and the files of key solutions and activation exercises in the form of e-textbooks. Mentioned materials were more widely used than individually created materials used from attendance of education. Probably

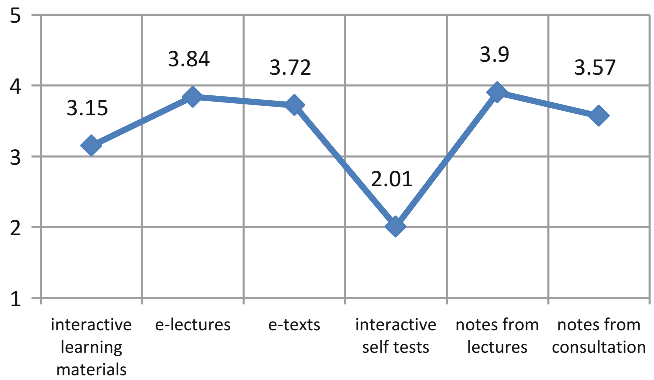

Fig. 7 Graphical illustration of using different types of study materials from mathematics subject

because the e-materials enabled them to study at the time which was the most suitable for them and also they need not to travel because of lecture as the many students do not live in the place of education. The least often they used the interactive auto tests.

Conclusion

Didactical effectiveness of proposed education model with the application of information and communication technologies was verified by educational experiment, realized within KEGA project. Three years' worth of results is presented to demonstrate the positive impact on students' results by the usage of new teaching model. The results of experiments showed that the application of proposed teaching model may increase the quality and of course the flexibility of mathematical subjects of study taught at technical university.

Acknowledgment Contribution was published thanks to grant KEGA. 021STU-4/2011.

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Efficient High-Level Coding in a PLC to FPGA Translation and Implementation Flow

Christoforos Economakos and George Economakos

Abstract

In the automation industry, PLCs have been the preferred implementation platform for many decades, due to their reliability, robustness and flexibility characteristics. However, the advances of the electronics industry have always kept automation engineers busy, looking for alternative platforms, proposed for the most demanding applications. Recently, the introduction of powerful and energy efficient FPGA devices has turned their interest towards methodologies to implement PLC applications with FPGAs, in automated or semi-automated ways. This paper evaluates such a methodology, which involves a fresh and productivity boosting technology, C-based FPGA programming. As FPGAs have made hardware designs wider accepted (compared to ASICs), C-based FPGA programming promises to make them even wider accepted (compared to HDL programming), provided specific, hardware related C-level coding guidelines are followed, that can greatly improve quality of results. The proposed methodology in this paper starts form low level PLC code (IL/STL) and after a disassembly-like phase, generates C code ready for FPGA programming. Through experimentation with demanding applications that involve floating point calculations, it is shown that when proper C-level coding guidelines are followed, performance gains (faster hardware) of up to 90 % can be achieved.

Keywords

Digital control • Hardware design • High-level synthesis • Coding styles

Introduction

Programmable Logic Controllers (PLCs) are the most commonly used computing devices in factory automation and industrial control. Although PLCs have been around since 1968 [1], they are still preferred by designers in industrial automation tasks because they offer fast development cycles, reliability and robustness. However, with the introduction of fast MEMS sensors and actuators, the growing demand for the implementation of more complicated control algorithms and the preference towards high precision floating point calculations, it has been made clear that traditional PLCs are not powerful enough to cover the needs of all practical applications. For this reason researchers in both academia and industry have never stopped investigating for other kinds of solutions. This quest for good alternatives to PLC technology is almost as old as PLC technology itself [1].

An attractive implementation technology for any type of digital circuit is *Field Programmable Gate Arrays* (FPGAs). FPGAs consist of programmable logic elements connected with a programmable interconnection network. The designer

This work was implemented through the Operational Program "Education and Lifelong Learning" and is co-financed by the European Union (European Social Fund) and Greek national funds.

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_36,

can program the logic elements to perform any primitive operation and the interconnection network to combine them appropriately, so that any given function can be implemented in an FPGA device. FPGA implementations offer low implementation cost, high flexibility and greatly improved performance over software. Recently, the technological advances in FPGA devices, offering hundreds of GFLOPs with maximum power efficiency, has turned diverse engineering communities towards them. However, FPGA programming requires specific expertise as well as the appropriate tools and methodologies, with which these communities are not always familiar.

This trend has entered the community of PLC programming also, with a number of approaches [2–12] translating PLC programs into *Hardware Description Languages* (HDLs) like VHDL and Verilog, in an automated or semi-automated way, in order to address the demand for FPGA expertise and speedup development time. This approach has given interesting results, but when demanding floating point calculations are needed, C-based hardware design, involving *High-Level Synthesis* (HLS) and *Electronic System Level* (ESL) [13] design platforms has been proposed [4, 5]. HLS starts with a behavioral or algorithmic description written in C/C++ and through different architectural optimizations produces an equivalent *Register-Transfer Level* (RTL) hardware description, optimizing design goals that have to do with user requirements (performance, available resources, power consumption) and I/O constraints. The advantages of C-based hardware design are smaller and abstract models, fast simulation and implementation times, better design space exploration and the use of widely accepted programming techniques. The disadvantage is that for the efficient mapping between algorithmic and architectural descriptions, specific and some times tool dependent C-level coding guidelines must be followed. Inefficient algorithmic descriptions produce inefficient implementations and thus, a new design methodology must be followed.

The contribution of this paper is the incorporation of specific C coding styles in the PLC to FPGA implementation flow presented in [4, 5], which translates PLC code into C/C++ and uses the CatapultC (http://www.calypto.com/catapult_c_synthesis.php) HLS toolset for C-based hardware design. The proposed design flow uses floating point calculations, utilizing a software operator library that gets mixed with the control algorithm into a common description. This common description is translated as a whole into an implementation architecture, removing strict operator bounds imposed by HDL hardware design. With this approach, common subexpressions or forward and reverse transformations between different operator instances are optimized away, resulting in more efficient implementations. As it is shown in the experimental results, algorithmic optimizations (coding styles) outperform architectural optimizations (HLS optimizations) and thus their incorporation in our flow gives added value to the whole process, and offers a highly efficient platform for PLC to FPGA translation.

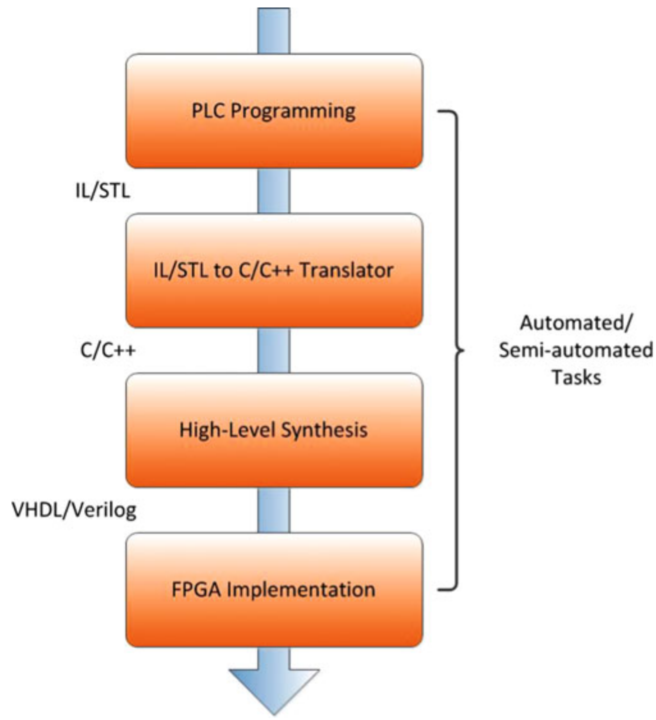

Fig. 1 The proposed design flow

Proposed Design Environment

The design methodology proposed in this paper is based on the ideas presented in [4], for the translation of PLC programs into FPGA implementations. The corresponding design environment is shown in Fig. 1. First, a PLC programming environment is used to generate a PLC program in the *Instruction List*, or also called *Statement List* (IL/STL) language. This is a straightforward task for a control engineer. Next, a custom built translator is used to translate IL/STL into C/C++, following specific coding styles to improve the results of C-based hardware synthesis. The next step is an HLS toolset, which takes this algorithmic optimized C/C++ and produces an HDL architectural description. Finally, the HDL description is given to an FPGA implementation toolset for final realization. All step are automated or semi-automated (some user interaction is required, even if script files are automatically generated) so, a little extra knowledge is required from a control engineer. The proposed environment can be used to design various control applications, using either fixed or floating point operators. Especially for floating point operators, the incorporation of HLS gives an extra advantage over HDLs and RTL based design.

HLS Algorithmic and Architectural Optimizations

Following this approach, the two main tasks provided by the presented environment are algorithmic and architectural optimizations. Algorithmic optimizations are the special C/C++ coding styles incorporated in the STL to C translation tool. A general discussion of HLS specific coding styles can be found in [14]. In our environment, since STL is a low level programming language and contain (explicitly or inferred) much low level detail like loop boundaries and operator bitwidths, the following list of optimal code generation rules are applied in a constructive manner (from low level to high level):

1. Special bit accurate types ac int and ac fixed, provided by CatapultC, are used, offering simulation performance and synthesis quality.
2. Input and output signals are inferred by the top level function parameters and they way they are used, either read (input) or written (output).
3. Pass-by-value function input parameters require internal registers while pass-by-reference no. So, if an external circuits (i.e. ADC) provides input registers, the latter is preferred.
4. Function output parameters are registered by default.
5. Loop boundaries should be fixed if possible, for decidable execution time. So, for loops are preferred than while and repeat loops, with as clear as possible start, increment and end statements.
6. Conditionals are explicitly denoted mutually exclusive with if . . . else, for decidable execution time.
7. Parentheses can be used to force height reduction and common subexpression elimination.
8. Loops are first attempted to be merged or nested and then hierarchically separated, to improve parallelization opportunities.
9. The use of constant multipliers and shifts is much preferred than general purpose multipliers.
10. Arrays mapped to memories can be optimized for speed, by widening the memory I/O bitwidth (i.e. 64 bit I/O ports for 32 bit operands), allowing more than one parallel memory accesses.
11. Arrays mapped to memories can be extended so as their size is a power of 2, for simpler controller generation and performance improvements.
12. Arrays mapped to register files are initialized with a special static function, described in the CatapultC documentation, and not with a traditional C loop. The former will generate correct initialization hardware, connected with the global circuit reset signal, while the later will generate useless initialization hardware, activated in every clock cycle.
13. Global variables are avoided because they generate useless register control hardware.
14. Static variables always generate registers and can be initialized in the traditional C style, in their declaration.

All rules are applied through command line arguments. This way, some rules that may or may not improve design performance (for example, rules 7 and 8) are first tested before final decisions are made.

Architectural optimizations are supported by CatapultC and may be applied through GUI manipulations or script files (used to automate the HLS process). In brief, they are the following:

1. Loop pipelining, which is controlled by the initiation interval directive. This directive takes numeric values as arguments and denotes that each loop iteration will wait that number of control steps before it starts. For a loop with no data dependencies between the operations in each iteration, all iterations can be performed in parallel. For a loop with strong data dependencies between the operations in each iteration, each iteration may be forced to be performed only after the previous has completely finished. Usually, feasible solutions lie in the middle. When one loop iteration partially overlaps another, CatapultC generates a pipelined algorithm implementation which gets faster as the initiation interval directive gets smaller (minimum value is 1 control step). Loop pipelining is a throughput optimization and gives better results if applied in the outer loops in nested loop configurations.
2. Loop unrolling, which is the duplication of the loop body a number of times, denoted by the CatapultC unrolling directive. Since each loop iteration takes at least 1 control step to finish, by duplicating the iteration we investigate the opportunity to put more operations within this limit and lower the repetitions and thus, get faster hardware. Very long values result in long run times for the tool and tend to serialize the whole loop, which may prevent pipelining, so they are avoided. Loop unrolling is a latency optimization and gives better results if applied in the inner loops of nested loop configurations.
3. Loop merging, which can combine loops with identical bounds. Normally, CatapultC schedules consecutive loops found in source code one after the other, with no overlapping. If the loops however have identical bounds and data dependencies permit it, both loops can be executed in parallel, by merging their corresponding iterations. This technique offers savings in loop control hardware and is enabled by an appropriate directive.
4. Memory map threshold. CatapultC can map data objects either in register files or in memories. Small data objects can be mapped in register files, with very fast access times but more complicated control logic. Register files

are implemented in FPGAs with *Look-Up Table* (LUT) elements. Large data objects can be mapped in memories with slower access times but less complicated control logic. Also, memories can be on-chip, like dedicated *Block RAM* (BRAM) in FPGAs, or off-chip. To control these options CatapultC uses a threshold directive. Data objects smaller than threshold are mapped into registers while objects larger than threshold are mapped into memories. Furthermore, each data object can be forced to be mapped in either type of resource. External memories can be used, for large global data objects, provided appropriate libraries are available. However, data access times in this case are a considerable performance drawback.

5. Internal memory organization. Internal memories in CatapultC have two properties that can affect performance. First, libraries are provided for both single or dual port memories. Second, each memory (either single or dual port) can be split into a number of blocks. Both properties, controlled by appropriate directives, increase the number of memory accesses in a single control step. On the other hand, complicated memory configurations require complicated control logic.

Architectural optimizations are also iteratively applied and tested before final decisions are made. For example initiation interval starts with large values (equal to loop boundaries) and is iteratively decreased while unrolling starts with a value of 2 and is iteratively increased up to the loop boundary.

Experimental Results

In order to evaluate the proposed design flow, three flavors of the *Proportional-Integral-Derivative* (PID) algorithm have been implemented. The first was the simple PID algorithm, the second the fuzzy PID algorithm used in the lopper control of a rolling mill reported in [15] and the third, the adaptive or tuning fuzzy PID algorithm found in the same publication. All implementations used floating point calculations, taken from a software open source library (http://www.jhauser.us/arithmetic/SoftFloat.html). So, the C code used for hardware synthesis was the control algorithm translated from STL (i.e. one of the three PID flavors), together with the operator library. All algorithmic and architectural optimizations reported in the previous section were applied to both code components, resulting in deep optimization and design space exploration, at the expense of longer run times. For all implementations, the Xilinx Virtex-6 6VLX240 FPGA device at 200 MHz was used.

The simple PID algorithm is given below (y is the system output, yp the reference command, e the error, u the system input or controller output and kp, ki, kd the controller scaling factors).

$$
\begin{aligned}
&e = y - yp\\
&p = kp * e\\
&sum = sum + e\\
&i = ki * sum\\
&d = (e - laste) * kd\\
&laste = e\\
&u = p + i + d
\end{aligned}
$$

Implementation details about the simple PID controller are given in Table 1. Four solutions have been implemented, PID *no*, with no optimizations applied, PID *arch*, with only architectural optimizations applied, PID *alg*, with only algorithmic optimizations applied, and PID *arch* + *alg*, with both architectural and algorithmic optimizations applied. For each solution, performance (latency and throughput, for pipelined architectures) and area (Look-Up Table function generators—LUTs, D-type Flip-Flops—DFFs, special Digital Signal Processing blocks—DSPs) measurements are given both in absolute values as well as percentages with respect to the no optimization solution (PID *no*). Positive percentage values correspond to improvements while negative to overheads. The last row (percentages in boldface), is a comparison between the solution with only architectural optimizations applied (PID *arch*) and the solution with both architectural and algorithmic optimizations

Table 1 Implementation of the PID controller

			Area		
Sol/on	Latency	Thr/put	LUTs	DFFs	DSPs
PID *no*	245.49	95.53	11277	4093	1
PID *arch*	131.93 46.26 %	40.08 59.32 %	23546 −108.80 %	9881 141.41 %	4 −300 %
PID *alg*	83.5 65.99 %	26.72 72.88 %	119.23 −5.73 %	3509 14.27 %	5 −400 %
PID *arch* + *alg*	83.5 65.99 % **36.71 %**	11.69 88.14 % **70.83 %**	17203 −52.55 % **26.94 %**	13625 232.89 % **−37.89 %**	9 −800 % **−125 %**

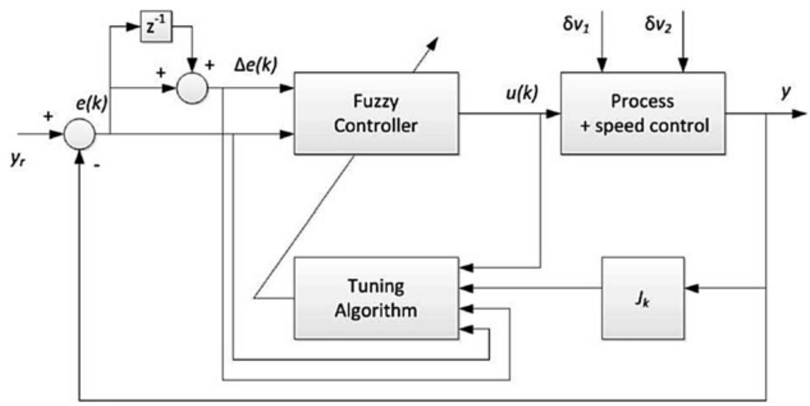

Fig. 2 The structure of the lopper control system

applied (PID *arch* + *alg*). As it can be seen, in all cases, faster solutions require more hardware, as expected. However, when only algorithmic optimizations are applied (PID *alg*), large performance improvements are reported (72.88 % better throughput) with small area overheads or even gains (14.27 % less DFFs). When combining architectural and algorithmic optimization (PID *arch* + *alg*), overall best performance is achieved (almost 90 % better throughput), with large however area overheads, compared to the no optimization solution. This overhead is not as high however, when compared with the solution with only architectural optimizations (boldface percentages). Furthermore, area overheads are not so crucial in FPGAs, because they do not impose any extra cost, as long as enough resources are available in the selected device. Overall, the results in Table 1 show that algorithmic optimizations have a much more critical impact on the final performance and area requirements.

The fuzzy PID controller found in [15] is shown in Fig. 2, in its full, adaptive flavor (the non adaptive flavor is the same, without the Tuning Algorithm block). The corresponding equations are given below.

$$
\begin{aligned}
&e = y - yp\\
&de = e - lastde\\
&x1 = \frac{e}{Kin1}\\
&x2 = \frac{e}{Kin2}\\
&mNB = 1 - \frac{abs(x1 - NBa)}{(NBb >> 1)}\\
&mNS = 1 - \frac{abs(x1 - NSa)}{(NSb >> 1)}\\
&mPS = 1 - \frac{abs(x1 - PSa)}{(PSb >> 1)}\\
&mPB = 1 - \frac{abs(x1 - PBa)}{(PBb >> 1)}\\
&mN = 1 - \frac{abs(x2 - Na)}{(Nb >> 1)}\\
&mZ = 1 - \frac{abs(x2 - Za)}{(Zb >> 1)}\\
&mP = 1 - \frac{abs(x2 - Pa)}{(Pb >> 1)}\\
&den = (mNB + mNS + mPS + mPB) * mN +\\
&\qquad (mNB + mNS + mPS + mPB) * mZ +\\
&\qquad (mNB + mNS + mPS + mPB) * mP\\
&num = (mNB * w1 + mNS * w2 + mPS * w3 + mPB * w4)\\
&*mN + (mNB * w5 + mNS * w6 + mPS * w7 + mPB * w8)\\
&\quad *mZ + (mNB * w9 + mNS * w10 + mPS * w11 +\\
&mPB * w12) * mP\\
&quot = \frac{num}{den}\\
&u = Kout * quot\\
&laste = de
\end{aligned}
$$

The main control parameters are the same as the simple PID case, while the controller output $u = [x1,\ x2]^T$ or $u = [e/Kin1,\ \Delta e/K\ in2]^T$ ($K\ in1$ and $K\ in2$ are scaling factors) is based on a fuzzy logic method and consists of three stages: fuzzification, decision making and defuzzification. For fuzzification, the linguistic variables for $x1$ take the values of NB (Negative Big), NS (Negative Small), PS (Positive Small) or PB (Positive Big), while for $x2$ take the values N (Negative), Z (Zero) or P (Positive), with all membership functions being triangular and limits [NBa,NBb], [NSa,NSb], [PSa,PSb], [PBa,PBb], [Na,Nb], [Za,Zb] and [Pa,Pb] respectively. From this scheme, grade membership values mNB, mNS, mPS, mPB, mN, mZ and mP are calculated. For decision making, a set of Mamdani heuristic fuzzy rules have been selected, associating a real value w_i with each rule. Finally, defuzzification follows the pattern of the Takagi-Sugeno controller, where u is the quotient of the sum of grade memberships multiplied by rule w_i values, over the sum of a set of production t-norms, one for each Mamdani rule.

Implementation details about the fuzzy PID controller are given in Table 2, following the solution order of Table 1.

Table 2 Implementation of the fuzzy PID controller

Sol/on	Latency	Thr/put	Area LUTs	Area DFFs	Area DSPs
FPID *no*	512.69	170.34	17661	6347	3
FPID *arch*	472.61 7.82 %	172.01 −0.98 %	63949 −262.09 %	25012 −294.08 %	3 0 %
FPID *alg*	325.65 36.48 %	145.29 14.71 %	17508 0.87 %	6333 0.22 %	 −133.33 %
FPID *arch + alg*	312.29 39.09 % **33.92 %**	123.58 27.45 % **28.16 %**	48821 −176.43 % **23.66 %**	29046 −357.63 % **−16.13 %**	11 −266.67 % **−266.67 %**

Again, while performance gains are this time significant but less impressive (almost 30 % in throughput), algorithmic optimizations improve design quality in a much more critical way than architectural.

The final controller flavor, the fuzzy adaptive PID, is operators and/or membership functions. In [15], membership function tuning was performed using both back propagation and descent methods. In brief, the tuning part (more details can be found in [15]) is given by the following equations, which together with the previous equations for the fuzzy non-adaptive controller, form the fuzzy adaptive controller.

Preliminary Computations

$$temp1 = u*(mN + mZ + mP)$$
$$sNB = Kout*(mN*w1 + mZ*w5 + mP*w9) - temp1$$
$$sNS = Kout*(mN*w2 + mZ*w6 + mP*w10) - temp1$$
$$sPS = Kout*(mN*w3 + mZ*w7 + mP*w11) - temp1$$
$$sPB = Kout*(mN*w4 + mZ*w8 + mP*w12) - temp1$$
$$temp2 = u*(mnB + mNS + mPS + mPB)$$
$$sN = Kout*(mNB*w1 + mNS*w2 + mPS*w3 + mPB*w4) - temp2$$
$$sZ = Kout*(mNB*w5 + mNS*w6 + mPS*w7 + mPB*w8) - temp2$$
$$sP = Kout*(mNB*w9 + mNS*w10 + mPS*w11 + mPB*w12) - temp2$$

Calculate Gradients

$$dNBa = \frac{sNB}{den*NBb}$$
$$dNBb = (1 - mNB)*dNBa$$
$$dNBa = dNBa << 1$$
$$if(x2 < NBa)\, dNBa = -dNBa$$
$$dNSa = \frac{sNS}{den*NSb}$$
$$dNSb = (1 - mNS)*dNSa$$
$$dNSa = dNSa << 1$$
$$if(x2 < NSa)\, dNSa = -dNSa$$
$$dPSa = \frac{sPS}{den*PSb}$$
$$dPSb = (1 - mPS)*dPSa$$
$$dPSa = dPSa << 1$$
$$if(x2 < PSa)\, dPSa = -dPSa$$
$$dPBa = \frac{sPB}{den*PBb}$$
$$dPBb = (1 - mPB)*dPBa$$
$$dPBa = dPBa << 1$$
$$if(x2 < PBa)\, dPBa = -dPBa$$
$$dNa = \frac{sN}{den*Nb}$$
$$dNb = (1 - mN)*dNa$$
$$dNa = dNa << 1$$
$$if(x2 < Na)\, dNa = -dNa$$
$$dZa = \frac{sZ}{den*Zb}$$
$$dZb = (1 - mZ)*dZa$$
$$dZa = dZa << 1$$
$$if(x2 < Za)\, dZa = -dZa$$
$$dPa = \frac{sP}{den*Pb}$$
$$dPb = (1 - mP)*dPa$$
$$dPa = dPa << 1$$
$$if(x2 < Pa)\, dPa = -dPa$$
$$dw1 = \frac{m1}{den}, dw2 = \frac{m2}{den}$$
$$dw3 = \frac{m3}{den}, dw4 = \frac{m4}{den}$$
$$dw5 = \frac{m5}{den}, dw6 = \frac{m5}{den}$$
$$dw7 = \frac{m7}{den}, dw8 = \frac{m8}{den}$$
$$dw9 = \frac{m9}{den}, dw10 = \frac{m10}{den}$$
$$dw11 = \frac{m11}{den}, dw12 = \frac{m12}{den}$$
$$J = \frac{y - lasty}{u - lastu}$$

Table 3 Implementation of the fuzzy adaptive PID controller

Sol/on	Latency	Thr/put	Area LUTs	DFFs	DSPs
FAPID *no*	N/A	N/A	N/A	N/A	N/A
FAPID *arch*	662.99	260.52	217513	55578	3
FAPID *alg*	N/A	N/A	N/A	N/A	N/A
FAPID *arch + alg*	460.92 **30.48 %**	260.52 **0 %**	262918 **−20.87 %**	68612 **−23.45 %**	7 **−133.33 %**

Update

$$
\begin{aligned}
&acoef = Ka * e * J\\
&bcoef = Kb * e * J\\
&wcoef = Kw * e * J\\
&NBa = NBa + acoef * dNBa\\
&NSa = NSa + acoef * dNSa\\
&PSa = PSa + acoef * dPSa\\
&PBa = PBa + acoef * dPBa\\
&Na = Na + acoef * dNa\\
&Za = Za + acoef * dZa\\
&Pa = Pa + acoef * dPa\\
&NBb = NBb + bcoef * dNBb\\
&NSb = NSb + bcoef * dNSb\\
&PSb = PSb + bcoef * dPSb\\
&PBb = PBb + bcoef * dPBb\\
&Nb = Nb + bcoef * dNb\\
&Zb = Zb + bcoef * dZb\\
&Pb = Pb + bcoef * dPb\\
&w1 = w1 + wcoef * dw1\\
&w2 = w2 + wcoef * dw2\\
&w3 = w3 + wcoef * dw3\\
&w4 = w4 + wcoef * dw4\\
&w5 = w5 + wcoef * dw5\\
&w6 = w6 + wcoef * dw6\\
&w7 = w7 + wcoef * dw7\\
&w8 = w8 + wcoef * dw8\\
&w9 = w9 + wcoef * dw9\\
&w10 = w10 + wcoef * dw10\\
&w11 = w11 + wcoef * dw11\\
&w12 = w12 + wcoef * dw12
\end{aligned}
$$

Implementation details about the fuzzy adaptive PID controller are given in Table 3. This time, the no optimization and only algorithmic solutions could not be realized (at least with the specific tool), due to advanced code complexity. However, again algorithmic optimization played a crucial role when combined with architectural, reaching a 30 % latency reduction.

Conclusions

While FPGAs are an appealing alternative implementation platform for industrial automation solutions, FPGA programming and HDL can bring obstacles to their wide acceptance. C-based FPGA programming can help engineers overcome these obstacles. However, C-based FPGA programming requires specific coding styles for efficient implementation. These coding styles, used in this paper in a PLC-to-FPGA translation environment, can offer large performance gains (up to 90 %) and keep resource usage overhead low and practical. Such results cannot be achieved with architectural optimizations alone, offered by HLS techniques.

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Modeling a Cold Rolling Mill for Optimization

Meshack M. Nzioki

Abstract

A mathematical model of a rolling mill is produced using models of its constituent components based on physical laws. These models are combined to form a nonlinear model for the whole rolling mill process. In order to design control systems for rolling mill, a multidimensional set of nonlinear differential equations is linearized and the behavior of the resulting linear differential equations are compared with the response of the nonlinear model. This was done by simulations in which the gap opening and the rolling speed were varied and their effect on gap opening and the inter-strip length variation.

Keywords

Nonlinear modeling • HAGC • Optimization • Linearization

Introduction

Accurate roll gap and roll speed control are important in achieving high quality products for metal sheets and strips. The roll speed affects the tension of the strip, the exit thickness and the product profile as the material passes through the rollers. The final exit height depends on the gap opening. Considering the strip dynamics between two adjacent rolling stands as shown in Fig. 5 the necessary rolling mill model will be developed here. Attention is focused on the last two stands in a four stand Tandem Rolling Mill (TCM).

The rolling process is highly interactive and as such is treated as a multivariable problem. The interactions are due to coupling from one stand to another and are properly handled through a loop/strip tension system analysis. Slippage occurs at stands while rolling and should be avoided as it leads to uneven surfaces [1]. With coupled inputs (i.e. the looper torque and the rolling speed) and outputs (i.e. the looper angle and tension), Watanabe and Kotera designed a decoupler [2], Dyusters came up with a multivariable proportional integral derivative (PID)[3] and Seki [4] offers a linear quadratic to minimize strip tension and the looper angle with Hearns and Grimble [2] developing a quantitative feedback control system by inferring the strip thickness from the roller force. Though the thickness inference has been adopted for years the introduction of laser sensors eliminates the inference offering real time data for the BISRA(**B**ritish **I**ron and **S**teel **R**esearch **A**ssociation) relation (11) [2]. By 1990 few controllers had been designed with interaction to the strip gauge [5]. Tools and sensors have been developed which can give accurate reading of the strip tension, looper angle and the torque [6]. This makes it possible to design an appropriate controller to reduce the interaction. The paper is structured such that section “System Description” gives the system description, section “The Nonlinear Equations” describes the necessary states space equations deduced from the mathematical model supported by the physical and metallurgical properties of metals. In section “Simulations and Results”, the nonlinear model simulation results will be presented and linearized. The linear state space equations allow controller design and optimization.

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_37,

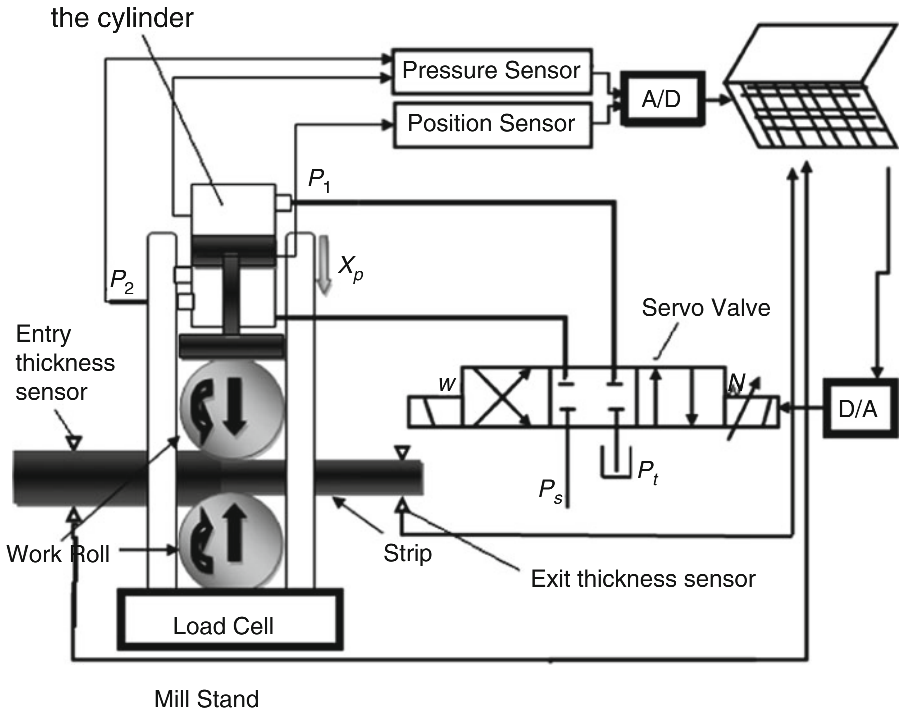


Fig. 1 A HAGC Schematic (*Source*: Yang and Zhang [7])

System Description

Force on the roller ensures the correct gauge. This is achieved by use of an Automatic Hydraulic Gauge Control (HAGC) that is favored for its characteristics. HAGC has a high bandwidth compared to other mechanisms such as Electric Automatic Gain Control (EAGC) and the screw-down method [7].

HAGC is schematically captured in Fig. 1. It consists of a hydraulic cylinder for force delivery, an Electro-hydraulic servo valve, Mill stands for rolling, sensors for taking the measurements, transmission lines for fluid delivery and Controllers to control the fluid flow and the gap opening [8, 9, 10, 11, 12, 13].

The dynamic analysis of a rolling model system is categorized using the constituent subsystems as:

(a) An Electro-hydraulic servo-valve system
(b) The rolling force
(c) The rolling process
(d) The stand rolling speed
(e) Inter-stand behavior.

With the help of the block diagram in Fig. 2, the constituent subsystems are elaborated.

The Hydraulic System

With reference to Figs. 1 and 2, the hydraulic fluid is pressurized by a pump driven by a variable motor. The pressurized fluid is regulated and stabilized by a relief valve and an accumulator. A servo valve, driven by an electric actuator (hydraulic cylinder) is used to control both pressure and flow rate. The system is completed via a feed-back digital control system [14].

Due to the force demand an electrodynamic servo valve system is used. The system is characterized by a nonlinear behavior as observed by [15, 16, 8, 13]. The large force is delivered over a small area and volume [17, 7]. From Newton's second law of motion by [18] the spool dynamics are given as:

$$\ddot{x}_v(t) = \frac{-f_s}{m}\dot{x}_v(t) - \frac{K_0}{m}x_v(t) + \frac{K_c}{m}u_i(t) \tag{1}$$

where m is the mass of spool piston, $K_c u_i$ is the applied input force, x_v is the spool displacement, f_s is the friction force contribution in the spool, K_o is the pivot pilot spring rate while K_c is the torque constant with $u_i = i_{in}$ being the applied input current. In terms of Laplace transform (1) is represented as:

$$ms^2 X_v(S) + sf_s X_v(s) + K_0 X_v(s) = K_c I_{in}(s) \tag{2}$$

The basic flow is given by:

$$Q = K_q A_0 \sqrt{\Delta P_v} \tag{3}$$

where Q is the pressurized fluid flow, K_q is a flow constant with A_0 being the orifice area and $\Delta P_v (= P_1 - P_2)$ represents

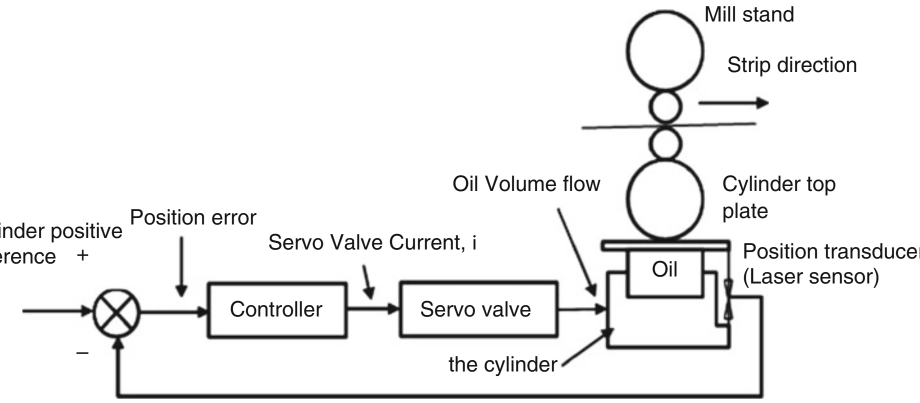


Fig. 2 The thickness delivery block diagram (*Source*: Khosravi et al. [8])

the pressure drop across the orifice. The Pressure developed in the system is:

$$pressure, P = \int \frac{1}{C_h} Q dt$$
$$Flow, Q = \sum q_i \tag{4}$$

where $C_h \left(= \frac{V_t}{\beta}\right)$ the equivalent hydraulic capacitance of an element and q_i is the constituent flow on each port. With the two chambers in consideration [8]:

$$\dot{P}v(t) = \frac{4\beta_e}{V_t}\{A_p \dot{x}_p(t) + K_{ce} P_p(t) - Q(t)\} \tag{5}$$

with V_t and β being the volume cavity and bulk modulus of oil respectively, x_p (t) is the piston position at the chamber relative to the cylinder body, A_p is the active piston area working cavity. The flow in and out of the chamber is through the two transmission lines with subscripts 1 and 2 in Fig. 1. It is given as:

$$q_1(t) = Q_0\left(\frac{x_v(t)}{x_{max}}\right)\sqrt{\frac{P_s - P_1(t)}{P_s}}, x_v > 0$$
$$q_2(t) = Q_0\left(\frac{x_v(t)}{x_{max}}\right)\sqrt{\frac{P_2(t)}{P_s}} \tag{6}$$

$$q_1(t) = Q_0\left(\frac{x_v(t)}{x_{max}}\right)\sqrt{\frac{P_1(t)}{P_s}}$$
$$q_2(t) = Q_0\left(\frac{x_v(t)}{x_{max}}\right)\sqrt{\frac{P_s - P_1(t)}{P_s}}, x_v < 0 \tag{7}$$

where Q_0 is the rated no load flow at the valve, x_{max} is the maximum spool displacement, P_s is the pressure supply, with P_1 and P_2 representing the pressure through the transmission lines. The pressure is given by:

$$\dot{P}_1(t) = \frac{4\beta_e}{V_t}\{(q_1 - A_p\dot{x}_p(t)) + K_{ce}(P_1(t) - P_2(t))\}$$

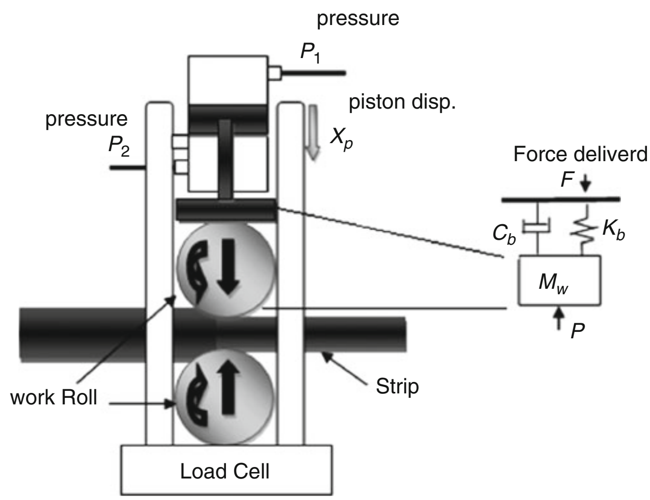


Fig. 3 Roll structure with force dynamics (Adapted from: Yang and Zhang [7])

$$\dot{P}_2(t) = \frac{4\beta_e}{V_t}\{(-q_2 + A_p\dot{x}_p(t)) + K_{ce}(P_1(t) - P_2(t))\} \tag{8}$$

The pressure developed is used to drive the rollers to the respective gap opening.

The Rolling Force

Once the pressure in the cavity has been established, it is used to deliver the required force for rolling. The gap opening is controlled by the delivered force. This is directly proportional to the piston movement X_p at the cylinder as indicated in Fig. 3

Applying Newton's second law of motion to the cylinder piston and with reference to Fig. 3, the force dynamics relate as:

$$\sum F_{cyl} = M_w \ddot{x}_p(t) = -f_{cyl}\dot{x}_p(t) - \Delta P - p_{s1} - p_r + p_{11} + F_{i2} \tag{9}$$

where $F_{i2} = P_p A_p$ the desired force at the cylinder, M_w is mass equivalent of all the moving parts at the chamber, p_{s1} is the positive bending force, p_{11} is the retro-force of back cavity, f_{cly} is the friction contribution and P is the rolling force.

The Rolling Process

Using Rowans proposal, Ravish [8], the rolling force is given by:

$$P = 1.2KW\sqrt{R'(H_i - h_i)} \tag{10}$$

where i represents the mill stand number, K is the average yield stress. Using the BISRA gauge equation, the rolling force P , the gap opening, S_i and the exit height h_i are related as:

$$h_i = S_i + \frac{P}{M} \tag{11}$$

while the strip exit thickness is directly related to the hydraulic gap opening whose dynamic are as given in (14). The rolling gap S_i in the BISRA (11) is related to the piston displacement as:

$$\begin{aligned} h_i &= h_L \\ &= S_i - \Delta h_r \\ &= S_i - \left(X_p - \Delta h_j\right) \\ \Delta h_j &= \frac{\Delta F}{M_m} \end{aligned} \tag{12}$$

Using the gain controller displacement, Fig. 4, the desired strip thickness delivery is elaborated. The change in force P [15] is given by:

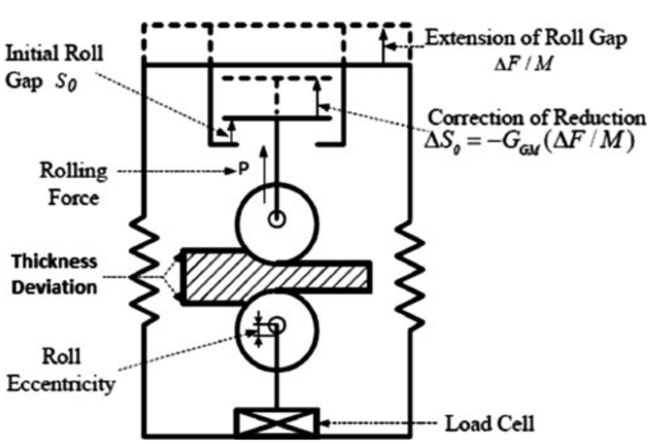


Fig. 4 Automatic gain controller displacement (*Source*: Yuan [12])

$$\begin{aligned} P &= \frac{M_0 W}{M_0 + W} x_p(t) + \frac{M_0}{M_0 + W}(F + W x_e) \\ &= K_S x_p(t) + w \end{aligned} \tag{13}$$

$K_s = M_0\ W/(M_0 + W\ )$, the synthesis rigidity of the rolling mill, x_e eccentricity displacement of the rolls, M_0 is the natural rigidity modulus of the rolling mill, and W is the plasticity as the material is being rolled [12]. Substituting (13) into (9), and transforming it to its Laplace equivalent we get:

$$\ddot{x}_p(t) = \frac{1}{M_w}\left\{-f_{cyl}\dot{x}_p(t) - Kx_p(t) + (F_{i2} - w)\right\} \tag{14}$$

the force resistance w is given as:

$$w = W\Delta h = W(H_i - h_i) \tag{15}$$

Δh is the strip thickness variance while rolling. With the force dynamic relation just established, the cylinder displacement describes a second order oscillatory motion. Equations (1) through (14) give the working model relations for a rolling stand dynamics. With ineffective elasticity on the milled strip, the exit height h_i is equated to the loaded gap of the working roll, h_L .

The Stand Rolling Speed

The behavior of the strip in the rolling direction is described by a first order differential equation [5, 19, 20, 21]. The rolling speed is derived from the roller angular speed as:

$$\dot{V}_{R_{i-1}}(t) = -\frac{1}{\tau_m} V_{R_{i-1}}(t) + \frac{1}{\tau_m} u_{V_{R_{i-1}}}(t) \tag{16}$$

τ_m is the motor mechanical time constant and $u_{V_{R_{i-1}}}(t)$ denotes the input to the feedback control system, $V_{R_{i-1}} = \omega_{i-1}\ R_{i-1}$, R_{i-1} is the roller radius. Figure 5 emphasizes the inter-stand interaction.

A variation of the roller speeds V_{Ri-1} and V_{Ri} is given by:

$$\overline{V} = V_{R_i}(t) - V_{R_{i-1}}(t) \tag{17}$$

Due to the interaction between the two stands via the strip, there is a cascaded effect on speed, $\overline{V}$ which will be handled by the controller in order to maintain the working speed to the correct set-points. The velocity cascaded technique will be deployed [22]. Here the variation of the speed ω_{i-1} suitably influences the upstream speed ω_i. A slight change say $\Delta\omega_i$ in the respective stand translates into a variation $\Delta\omega_{i-1}$ in the stand i according to (Fig. 6):

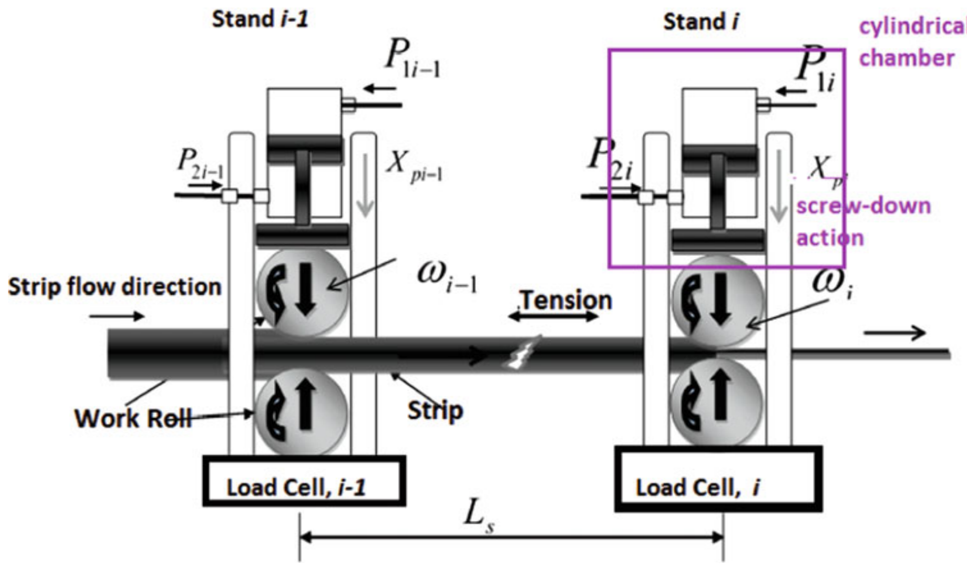


Fig. 5 Roller action for a 2 stand with inter-stand tension (Adapted from [7])

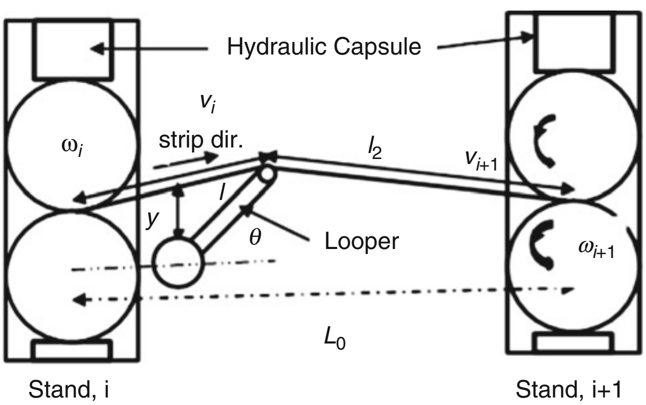


Fig. 6 Looper mechanism and strip dynamics (*Source*: Adapted from Park et. al [25])

$$\Delta\omega_{i_{ref}} = FF^{i-1}\omega_i + \frac{1}{(1+f_i)R'}\Delta\overline{V}_{ref} \tag{18}$$

where $\overline{V}_{ref}$ is as introduced in (17) as $\overline{V} = V_{R_i}(t) - V_{R_{i-1}}(t)$ and FF^i is an off-line coefficient estimated as follows:

$$FF^{i-1} = \frac{1+f^i}{1+f^{i-1}}\frac{H_{i-1}}{h_{i-1}} \tag{19}$$

and H_i is the entry height while h_i is the height at the exit end as earlier defined. In view of rolling change variation term indicated in (18), its dynamic is subject to the following relation:

$$\Delta\dot{V} = -\frac{1}{\tau_m}\overline{V} + \frac{1}{\tau_m}\overline{V}_{ref} \tag{20}$$

The Inter-Stand Behavior

As the strip flows through the stand, the strip dynamics will be manipulated to the correct set points. The rate of tension change is derived from Hooke's law and a consideration of the rate of inter-stand strip consumption, Yildiz [23]. This is in relation to the longitudinal stress and strain as defined by Young's modulus E [24].

This relation is given as:

$$\sigma(t) = E\left[\frac{L(\theta(t) - L_s(t))}{L_s(t)}\right] \tag{21}$$

where, l_1 and l_2 are the strip length stretch relations with respect to the looper position, L being the distance between the stands, a and y are the looper pivot point relative to the upstream stand and the baseline.

The strip tension should be controlled. If the right tension is not maintained then a recoil or strip breakage can occur when downstream roller moves faster than the upstream roller. The strip length depends on the tension and the looper angle. The looper stretches further as the strip length increases with the decrease in tension. As the rolling takes place, the extension is the difference between the geometric strip length, L_s depending on the looper angle θ and the length of the strip in the inter-stand $L_0 = L$ is:

$$L_s = L_0 + \int_{t_0}^{t}(V_{R_i}(t) - V_{R_{i-1}}(t))dt \tag{22}$$

This difference represents the strip variations when rolling [24, 26].

The Nonlinear Equations

The differential relations presented in section II describe the equations required to deliver the correct thickness at the desired tension and speed. Let the n state vector be $x(t) = [x_v, \dot{x}_v, P_1, P_2, x_p, \dot{x}_p, \omega_{Ri-1}, L_s]^T$ then the state equation $\dot{x}$ of the system is given

$$\dot{x}(t) = \begin{bmatrix} \frac{-f_s}{m}\dot{x}_v(t) - \frac{K_0}{m}x_v(t) + \frac{K_c}{m}u_i(t) \\ \frac{4\beta_e}{V_t}\left\{\left(q_1 - A_p\dot{x}_p(t)\right) - K_{ce}\left(P_1(t) - P_2(t)\right)\right\} \\ \frac{4\beta_e}{V_t}\left\{\left(-q_2 + A_p\dot{x}_p(t)\right) - K_{ce}\left(P_1(t) - P_2(t)\right)\right\} \\ \frac{1}{M_w}\left\{-f_{cyl}\dot{x}_p(t) - Kx_p(t) + (F_{i2} - w)\right\} \\ -\frac{1}{\tau_m}\omega_{R_{i-1}}(t) + \frac{1}{\tau_m}u_{\omega_{R_{i-1}}}(t) \\ \omega_{R_i}(t) - \omega_{R_{i-1}}(t) \end{bmatrix} \tag{23}$$

while the input vector $u(t)$ with p rows is:

$$u(t) = [u_i(t), u_{Ri-1}(t)] = [u1(t), u2(t)]^T \tag{24}$$

and the output vector $y(t)$ is defined as:

$$y(t) = \left[x_p, L_s, \omega_{Ri-1}\right]^T = [y1(t), y2(t), y3(t)]^T \tag{25}$$

Applying the parameters in Table 1 and using (1)–(22), the state space equations were obtained. These equations were simulated numerically in C++ using Runge-Kutta fourth order approximation.

The milling schedule was set as per Table 2, but only the fourth stand #4 will be detailed here.

Simulations and Results

Upon simulation, the time plots in Fig. 7a and 7b were obtained by stepping the input current and the rolling speed u_i and $u_{V_{R_{i-1}}}$ respectively.

The rolling speed varies from 6300mm/s on no load to 1,050 mm/s on full load.

Linearization

With the results displayed in Fig. 7 it is evident that both the rolling speed and the gap opening have an influence in the strip variations. The linear model is given by Fig. 7 and the transfer function matrix equation:

Table 1 Main parameters of thickness control system

Symbol	Parameters	Value
K_v	Servo Amplifier gain	Q_0/I_0
ω_{cyl}	Cylinder natural frequency	$2,600\sqrt{\frac{A_p}{Mh_h}}Hz$
ω_V	Servo valve natural frequency	$680\ Hz$
δ_V	Servo valve damping coefficient	0.7
A_p	Efficient Area of cylinder	$0.125663706\ m^2$
K_{ce}	Leakage coefficient	$7.8\times10^{-8}\ m^3/Pa.s$
h_h	Work oil high	$0.01\ m$
V_t	Cavity volume	$0.001257667\ m^3$
I_0	Rated current	$0.03\ A$
Q_0	Rated no-load flow	$5.33\times10^{-4}\ 9\ m^3/s$
β_e	Bulk modulus of oil	$800\ MN/m^2$
P_s	Pressure supply	$26\ MPa$
K_f	Feedback constant	$1\ V/m$
R	Work roll radius	$0.273\ m$
M_s	Modulus of Elasticity of steel	$200\ GPa$
M	Mass of the moving parts	$0.0067\ MKg$
M_m	Mill module	$4.9\times10^9\ N/m$
S_0	Unloaded roll gap	$3.5\times10^{-3}\ m$
δ_{cyl}	Cylinder damping coefficient	0.175
ρ^1	Hydraulic oil density	$0.92\ Kg/m^3$

Source: The above data was obtained from Xu et al. [13], authorized via personal email from Xing-Yuan XU.
ρ^1 is referenced from Sauer Danforce [27]

$$y_{nominal} = \begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \begin{bmatrix} \frac{34781}{s^2+40s+4347} & 0 \\ \frac{-2.27272}{s} & \frac{0.12}{s} \\ 0 & \frac{-3.75}{1+0.03s} \end{bmatrix} \begin{bmatrix} u_i \\ u_{V_{R_{i-1}}} \end{bmatrix} \tag{26}$$

From (26) it can be seen that both u_i and $u_{V_{R_{i-1}}}$ influence the strip variation response. As a way of minimizing the strip variations and adopting a working model structure, an internal controller for the roller speed was added. This led to incorporating a PI controller for the rolling speed $V_{R_{i-1}}$ with a unit feedback as shown in Fig. 8 whose output $y_3(t)$ becomes a driver for the strip inter-stand dynamics. The controlled motor is able to achieve a rolling speed of 1.05 m/s within 0.012 s while operating at maximum load. With reference to Fig. 8 $v1$ equals u_i while $v2$ equals ω_{i-1}^{ref}.

$$v(t) = [u_i(t), u_{VRi-1}(t)] = [v1(t), v2(t)] \tag{27}$$

To achieve this V_{R_i} was kept constant. The linearized model was obtained as:

Table 2 Roll scheduling table

Stand	h_{in} (mm)	Red.(%)	h_{out} (mm)	draft(mm)	ΔP (MN)	ΔP_p (MPa)	Q_i	Δh_r (mm)	Δh_j (mm)	x_p (mm)
#1	1.55	35	1.00100	0.549	8.200	11.21137544	4.9155	2.499	39.9415	42.4405
#2	1.00100	25	0.75075	0.25025	6.955	9.5091605	4.1692	2.74925	33.8772	36.6265
#3	0.75075	26	0.55556	0.19519	8.600	11.75827181	5.1553	2.9444	41.8899	44.8344
#4	0.55556	10	0.5	0.05556	5.906	8.074924802	3.5436	3.000	28.7677	31.76766

Piston area($\phi = 48.250\ cm$) $= 0.7314(m^2)$
W for Steel, Structural ASTM-A36, Modulus of Elasticity 200(GPa), source

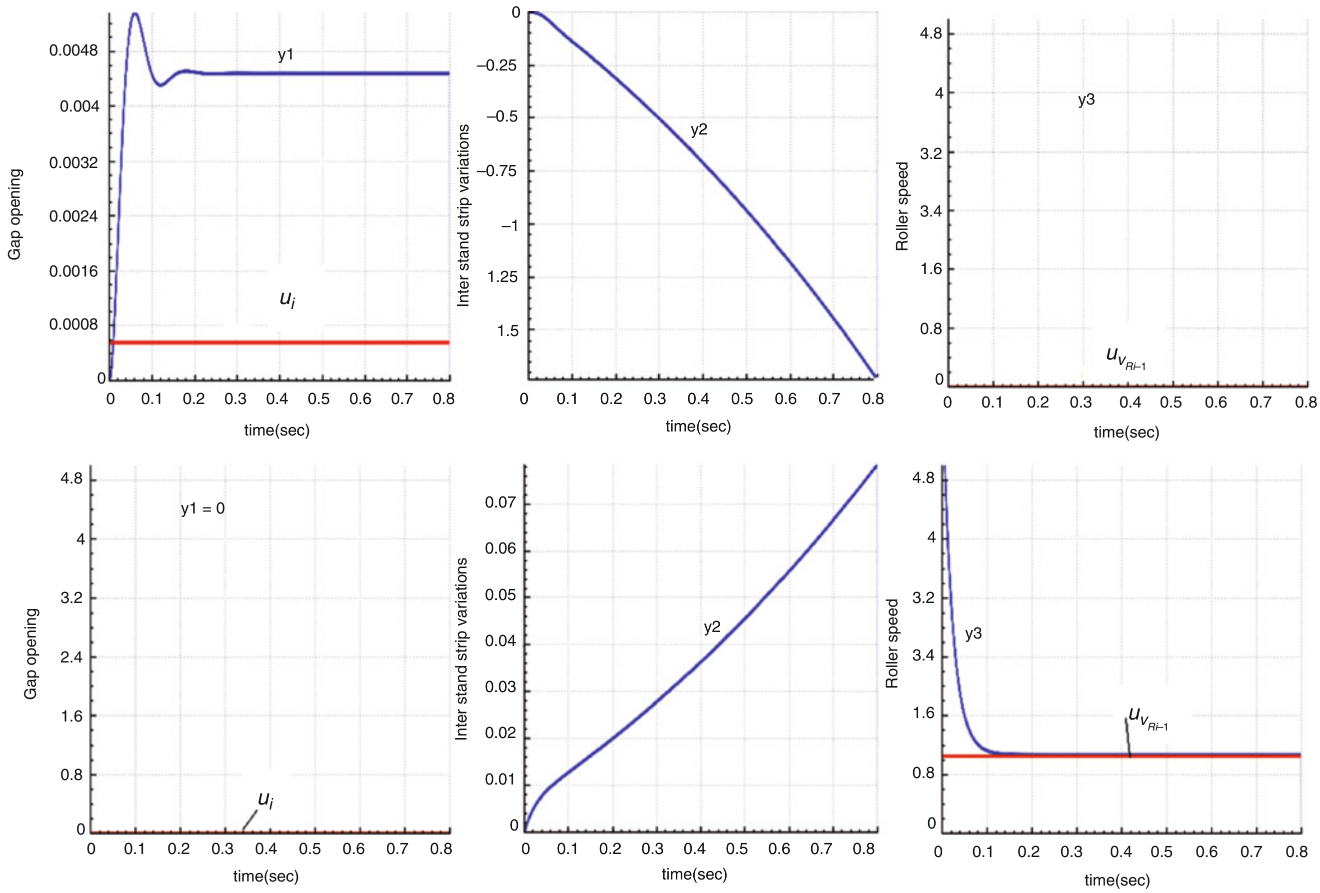
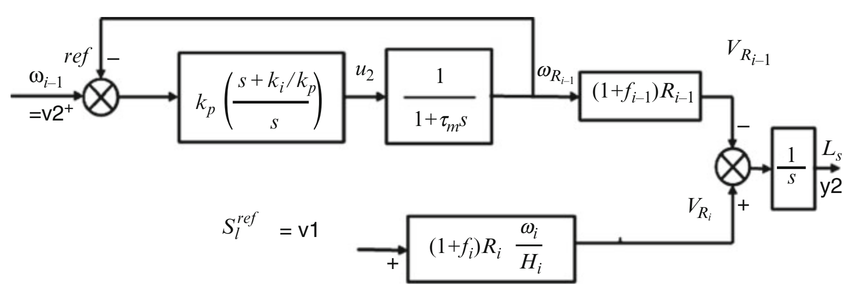


Fig. 7 Nonlinear simulation results (**a**) Step test with zero roller speed (**b**) Step test with zero input current and 1,050 mm/s

Fig. 8 Internal rolling speed control loop



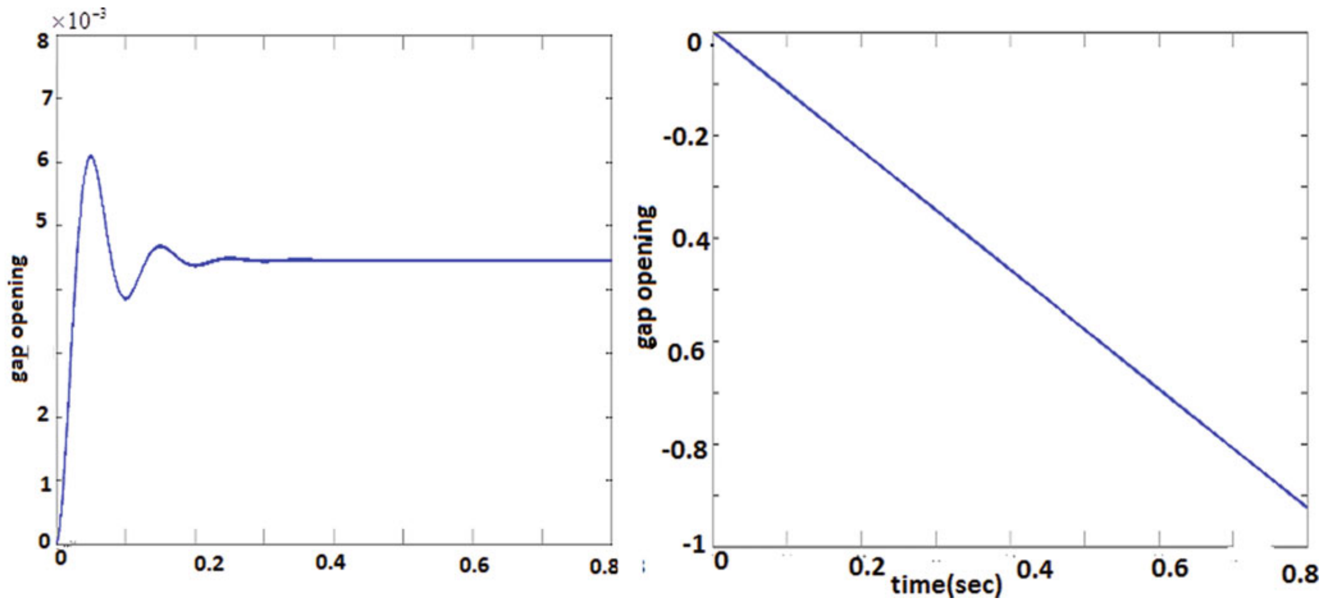


Fig. 9 Step test with zero roller speed

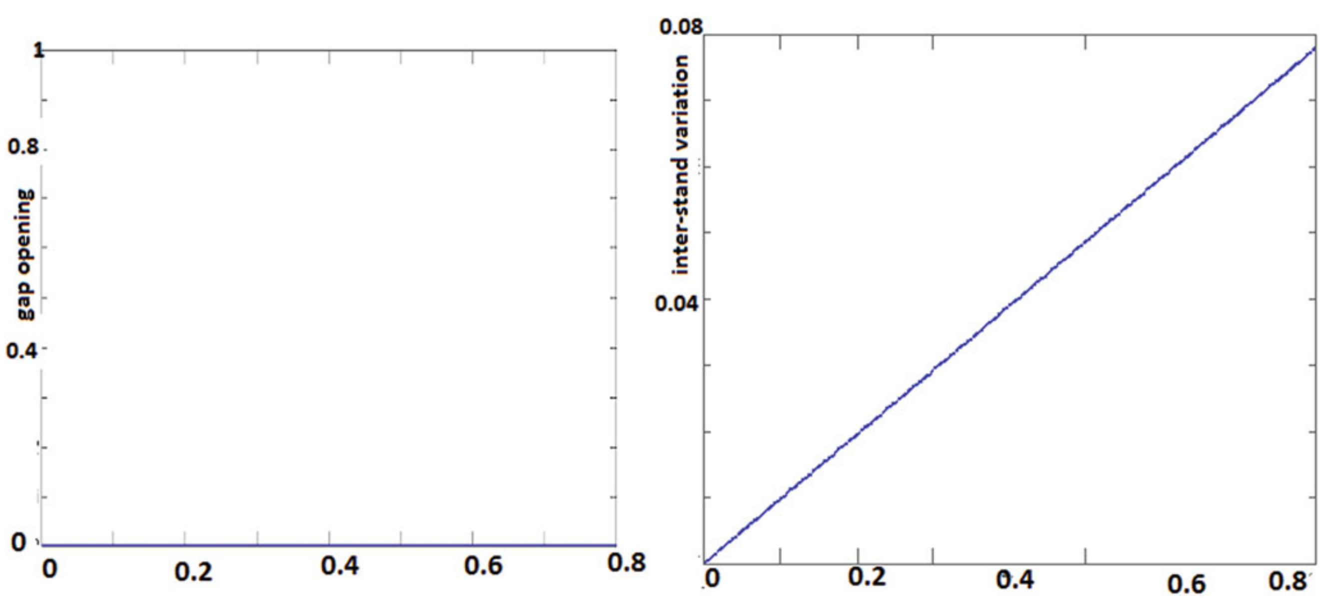


Fig. 10 Step test with zero input current and 1,050 mm/s

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} \dfrac{34781}{s^2+40s+4347} & 0 \\ \dfrac{-2.0833}{s} & \dfrac{0.09259}{s} \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} \qquad ((28))$$

Figures 9 and 10 were obtained upon simulating the linearized system.

The internal loop response was obtained as shown in Fig. 11.

Conclusion

A linear model has been successfully derived by linearizing a detailed, nonlinear mathematical model of a rolling mill process. It was observed that the transfer function matrix obtained was not a square. To rectify this an internal PI controller was incorporated to produce a 2×2 $MIMO$ system that can be used for the design of a controller and for process optimization.

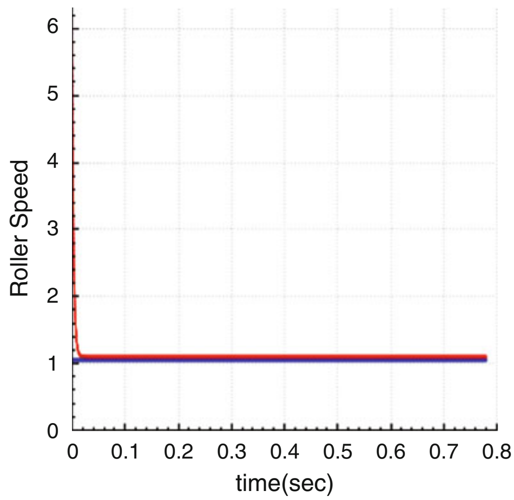


Fig. 11 Internal loop response

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Technological Development in Therapeutic Applications of Alternating Electric Fields: Review

S. Talele

Abstract

A number of bacteria, virus and other unhealthy cells need to be killed for getting rid of them. For more than a century antibiotics have been effectively used for killing bacterial pathogens and chemical drugs against the cancer cells. However, there are bacteria and cancer cells that are drug resistant. This may have to be overcome by other stronger drugs, higher dosage. These can have detrimental side effects. Other non drug methods to aid the effect of these drugs have always been in research. Electrochemotherapy, a method of using electric fields along with the drug to be used topically has been one of the successful approaches. One of the most recent methods of Tumor Treating Frequencies (TTF) for a brain cancer has been FDA approved. This article details the use of TTF. The article also details some other latest research where alternating fields are used as antibacterial agents.

Keywords

Alternating electric field • Biomedical applications

Introduction

The twentieth century was the modern era full of invention of antibacterial agents. Millions of people have been cured due to the treatment with the numerous antibiotic drugs used today. In the twenty-first century these antibacterial drugs surely play an important role in the battle against the ever increasing variety of bacteria. However, the extensive use of antibiotics holds a threat in the future due to the rapid rise of multi drug resistant bacteria. Recently, a number of alternative modes like weak electric currents [1–4], ultrasound wave therapy [5–7], thermotherapy [8], photodynamic therapy [9] have been studied. These are expected to aid the antibiotics in the battle against bacterial pathogens. They definitely have an advantage of being non-drug based. However, the main drawback of the above mentioned methods is the high level of heating produced by the ultrasound waves and thermography [10]. In addition, the activated oxygen produced by the use of photodynamic therapy, both of which can damage the tissues in and surrounding the target area [11].

In addition, electric currents which are generated by the use of conductive electrodes are associated with the release of metal ions and free radicals at the electrode surface. These are well known to be toxic to living cells [12]. As of today, none of the above-mentioned has been approved to be a method of treatment against bacterial control. However researchers have now shown that low intensity alternating fields of high frequencies have an in vitro inhibitory effect on growth of pathogenic bacteria.

Use of Alternating Fields: Background

Alternating electric fields have been used since many years for the diagnosis, research and treatment of various medical conditions. The properties and effect of such electric fields differ, depending on their frequency and intensity. Very low frequencies (lower than 1 kHz) are capable of exciting the

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_38,

membrane of muscles and nerves, thus leading to membrane depolarization which leads to action potentials [13–15]. These have applications like fracture healing Defibrillators and bone growth.

Higher frequency alternating electric fields penetrate cells better, but the overall effect of hyper-depolarization on the cell membrane counteracts with polarization in a way that the integrated stimulation does not yield an action potential. However, at frequencies higher than 10 MHz, process of dielectric polarization eventually heats the tissue [16, 17].

These find use in Diathermy and radio frequency tumor ablation. Intermediate-frequency alternating electric fields, at frequencies between 10 kHz and 1 MHz, neither cause effective depolarization nor significant dielectric losses. Thus, these intermediate frequencies cannot stimulate muscles ad nerves, but also cannot seriously heat tissues at low enough intensities. Electric fields at these frequencies were considered to have no useful biological effect on cells [16, 18] until recent times when researchers have mentioned that these ac fields can be used more effectively in electroporation based biological applications [19, 20]. These fields tend to be of higher intensity which can depend on the radius of the cell under investigation. Recently it has been found that such intermediate electric fields, have an effect that may lead to the death of dividing cells and thus named it as tumor treating fields (TTFields) [21, 22].

The fields were found to have these properties already at a very low intensity (<2 V/cm) and at intermediate frequency of 100–300 kHz [21, 22].

Facts About Tumour Treating Fields

TTFields's Mechanism of Action

Each cell contains numerous electrically charged molecules, such as proteins and DNA. When an alternating electric field is applied, these molecules will oscillate according to the changing direction of the field and its density. A uniform field will cause a movement parallel to the direction of the field. When the frequency of the field is high enough, such as in the case of TTFields, this molecular movement will reduce. Within a non-dividing cell, the field is mostly uniform and the net force on charges and dipoles will, therefore, yield minimal movement. Non-uniform electric fields cause electrophoresis forcing polar molecules to move toward higher field intensity [23, 24]. These high fields are at the furrow of a dividing cell called formed during mitosis. Such fields are characteristic of dividing cell when a narrow furrow connects the two forming daughter cells. Thus the electrical forces acting on the dividing cells affects in a way that mitosis becomes arrested for an abnormally long time [21]. It is reported that modelling results have shown that polarized molecules and organelles within the cell move toward the furrow due to the high dielectric force and disrupting the internal cell structure and cause the cell destruction [21].

Other Facts About Tumour Treating Frequency Fields

1. TTFields are generated by means electrically insulated ceramic electrodes, thus ensuring that no toxic ions are formed as there is no electrolysis [22] and can be effectively applied using surface electrodes [22].
2. TTFields can be delivered via a portable, light-weight (~3 kg) device carried by the patient (NovoTTFields-100A, NovoCure Ltd, Haifa, Israel), connected to two pairs of insulated electrodes that can be applied to the patients' skin [21, 22].
3. The device continuously (18 h/day on average) delivers two perpendicular 1–2 V/cm, 200 kHz alternating electric fields [21, 22].
4. The only treatment-related adverse event was mild-to-moderate contact dermatitis beneath the electrode gel, which was easily managed using topical treatments [21, 22].
5. TTFields was shown to inhibit proliferation and to cause cell destruction of many cancer cells in vitro and in vivo [21, 22].
6. There are no serious adverse events found related to TTFields as until now [21, 22].
7. Importantly, there were no cardiac or neurological abnormalities as a result of TTFields treatment [21, 22].
8. Due to non-invasive surface electrodes flow of ionic currents [25] or cell death [26] is prevented as compared to cell death as a result of direct currents, and thus continuous treatment is possible.
9. TTFields can actively inhibit different cell types, including multi-drug-resistant [21, 22].
10. TTFields does not need to be used along with any other therapy [21, 22].
11. Even though TTFields is a regional treatment, it still managed to decrease the likelihood of metastases formation in animal experiments [22].

Future of TTFields

This use of TTFields is one of the most recent researched non invasive, non drug method which is capable of inhibiting several cell types including multi drug resistant cell lines. Each cell line will be inhibited at an optimum frequency specific for the cell line [27] as shown in Table 1.

Table 1 Optimal frequency for different cell lines [27]

Cell line	Optimal frequency in kHz
B16F1 (mouse melanoma)	120
AA8 (Chinese hamster ovary)	150
VX-2 (rabbit kidney)	150
MCF-7 (human breast)	150
MDA-MB-231 (human breast)	150
F-98 (rat glioma)	200
U-87 (Human glioma)	200
U-118 (Human glioma)	200

With more research the treatment can be developed for further applications as follows:

1. There are also some data indicating that combining chemotherapeutic cancer treatments with TTFields may increase efficacy and sensitivity to chemotherapy [28].
2. TTFields is a regional treatment: it could be employed in situations where radiotherapy is not possible [27].
3. Even though TTFields is a regional treatment, it still manage to decrease the likelihood of metastases formation in animal experiments [29].

Antibacterial Effects if Alternating Fields

Recent studies using alternating fields using insulated electrodes have reported to be useful [30]. Following are some facts about the use of antimicrobial fields (AMfields).

1. AMFields applied using noninvasive, insulated electrodes, have a significant inhibitory effect on the growth of a pulmonary bacterial infection in mice [31].
2. The inhibitory effect was observed when AMFields were applied either as a monotherapy or as an aid to antibiotic therapy [31].
3. Inhibition of bacterial growth is dependent on frequency of AMFields ranging from 100KHz to 10 MHz with different bacteria being sensitive to a specific frequency [31].
4. The antibacterial effect is also field intensity dependent with a 30 % reduction reported at about 4 V/cm [30] for *S. aureus* (strain SH1000).
5. The relatively high frequencies at which the AMFields effect is observed may be used for application of high intensities required for deep tissue treatment without nerve or muscle stimulation [30].
6. Future applications of AMFields can include treatment for resistant and/or chronic infections or to accelerate the treatment of common infections, such as tonsillitis, pharyngitis or similar, all by itself or in parallel with antibiotics [30].

Conclusion

Alternating electric fields of intermediate frequencies when applied using non invasive electrically insulated electrodes have been reported to be beneficial in destroying some cancer cell lines and also have been found to have antimicrobial effects.

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Multi-Touch Gesture Recognition Using Feature Extraction

Francisco R. Ortega, Naphtali Rishe, Armando Barreto, Fatemeh Abyarjoo, and Malek Adjouadi

Abstract

We are motivated to find a multi-touch gesture detection algorithm that is efficient, easy to implement, and scalable to real-time applications using 3D environments. Our approach tries to solve the recognition for gestures with the use of feature extraction without the need of any previous learning samples. Before showing our proposed solution, we describe some algorithms that attempt to solve similar problems. Finally, we describe our code to accomplish off-line gesture recognition.

Keywords

Multi-touch • Feature extractions • User interfaces • 3D user interfaces • Human-computer interaction • Multi-touch recognition

Introduction

We present the initial development of our approach to detected gestures in a multi-touch display using a finite state machine and feature extraction. We described our methods in the context of important previous work, like the $1 algorithm [1] and the Rubine algorithm [2]. Our first approach to the problem is demonstrated with off-line data.

Gesture detection algorithms are not a new problem in Human-Computer Interaction (e.g., [3, 4]) and some have derived from stroke detection algorithms [5], as will be shown in our brief review of previous work. With the availability of multi-touch devices such as the iPad, iPhone and desktop multi-touch monitors (e.g., 3 M M2256PW 22″ Multi-Touch Monitor) new concepts have developed in order to help the transition to a post-Windows-Icon-Menu-Pointer (WIMP) era. The development of Natural User Interfaces (NUIs) presents many exciting challenges.

To solve the problem, we first reviewed previous work in the area of stroke and gesture detection relevant to our solution. After the related work section, we cover our proposed solution, and future direction.

Background

There have been various approaches to gesture recognition, like the use of finite state machines [6, 7], Hidden Markov Models [8], neural networks [9], dynamic programming [10], featured-based classifiers [2], and template matching [1, 11–13]. Thorough reviews can be found in [14–16]. For our work, we have looked in-depth at feature extraction recognition methods like the Rubine and $1 algorithms [1, 2].

Some of the methods used in handwriting recognition [15] can be used for gesture recognition [17]. While handwriting recognition efforts date as far back as the 1950s [15], it has been the work of Rubine [2] that has been used as a foundation by some in the gesture recognition area [1, 18] including us. While the Rubine algorithm [2] uses training with its features, we aim at finding features that can be used without training samples.

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_39,

We called the "$ algorithms" a partial list of approaches derived or inspired by work from $1 algorithm [1] such as [12, 13, 19, 20]. The $1 algorithm [1] provides a simple way to develop a basic gesture detection method. In contrast, algorithms based on Hidden Markov Models or neural networks [9] involve a high level of complexity for the developer and the system as well. $1 provides a very fast solution to interactive gesture recognition with less than 100 lines of code [1] and requires a simple training set. However, this is not meant for the recognition of multi-touch gestures and for prospective real-time gesture recognition. This does not diminish in any way the importance of the $1 algorithm because there are several features that make it important. For example, the obvious resampling of the gesture, the indicative angle ("the angle formed between the centroid of the gesture and [the] gesture's first point" [1]), and the re-scaling and translation to a reference point to keep the centroid at (0,0). Another important contribution is the use of the Golden Section Search [21] to find the right gesture. The "$ Algorithms" provide a rich set of contributions for the multi-touch research community.

The $N algorithm [12], with the double amount of code (240 lines), improves the $1 algorithm [1] to allow single strokes and rotation invariance discrimination. For example, to make a distinction between A and ∀, rotation must be bounded by less than ±90° [12]. The $N algorithm [12] was extended primarily to allow single strokes to be recognized. This algorithm also supports automatic recognition between 1D and 2D gestures by using "the ratio of the sides of a gestured's oriented bounding box (MIN-SIDE vs. MAX-SIDE)" [12]. In addition, to better optimize the code, it only recognizes a sub-set of the templates to process. This is done by determining if the start directions are similar, by computing the angle formed from the start point through the eighth point. A common feature of the $1 and $N Algorithms [1, 12] is the utilization of the Golden Section Search [21].

Additional algorithms provide great resources for future work. Dean Rubine provides an excellent set of features to be tested with multi-touch data. In addition to the Rubine algorithm [2], we can use Wang et al. [22] to find if the gesture was created with fingers in oblique position or not. Additional information can be found in our previous work [23].

Proposed Solution

Motivation

We are motivated to find a low-complexity implementation and a fast algorithm that can be utilized for high-demanding applications. In our case, our end goal is to use it with high-demanding 3D navigation environments using multi-touch displays. First, we are motivated by the work of Rubine [2] to find the best features to characterize a gesture while keeping the complexity low, as done by the $1 algorithm [1]. Second, we are motivated to find an unsupervised method of recognition that can be used in high-demanding real-time applications such as 3D synthetic worlds. Finally, we came across a multi-touch gesture detection problem statement created by Greg Hamerly in the ICPC 2012 Competition[1] [24] which resembles some of the work we have been doing with gesture detection. It is the combination of all the great work already mentioned plus our application needs, that have given us the path to follow in this proposed solution. Therefore, we believe that the path we propose, could serve as another building block for the development of POST-WIMP era interfaces.

Setup

We used Windows 7 multi-touch technology [25] with Microsoft Visual Studio and a 3 M M2256PW Multi-Touch Monitor to test our work and we have tested our approach with off-line data. Windows 7 provides either pre-defined touches or raw touches when using their technology. We chose to work with raw touches because it gives us the flexibility to create custom gestures and to test different methods for detection.

When using raw touches, most systems where multi-touch is available (e.g., iOS, Windows) will provide a "trace" which contains a set of points with coordinates x and y as well as a timestamp for each point. The system will also generate events when the trace is created, moved, and finished. Each touch has a unique identification (ID) that is given at the moment of TOUCHDOWN, to be used during the TOUCHMOVE, and to end when TOUCHUP has been activated. The ID gives us a way to group points from each finger. For specific information on how Windows 7 handles multi-touch technology, please see [25].

Method

We begin by combining feature extraction with a finite state machine [26], as shown in Fig. 1. The idea is to allow a state machine to keep control of the process in order to find a common system to make the changes. The state starts as idle like for any other input device. Here we have a state transition to the touch state with either down or move events. Once

[1] Francisco Ortega led one of the programming competition tutoring sessions (Fall 2012) at Florida International University.

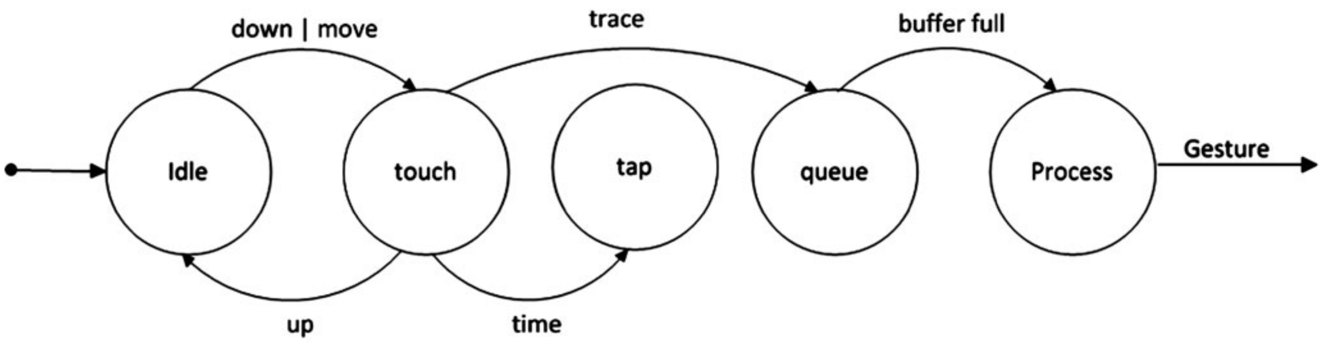

Fig. 1 State machine

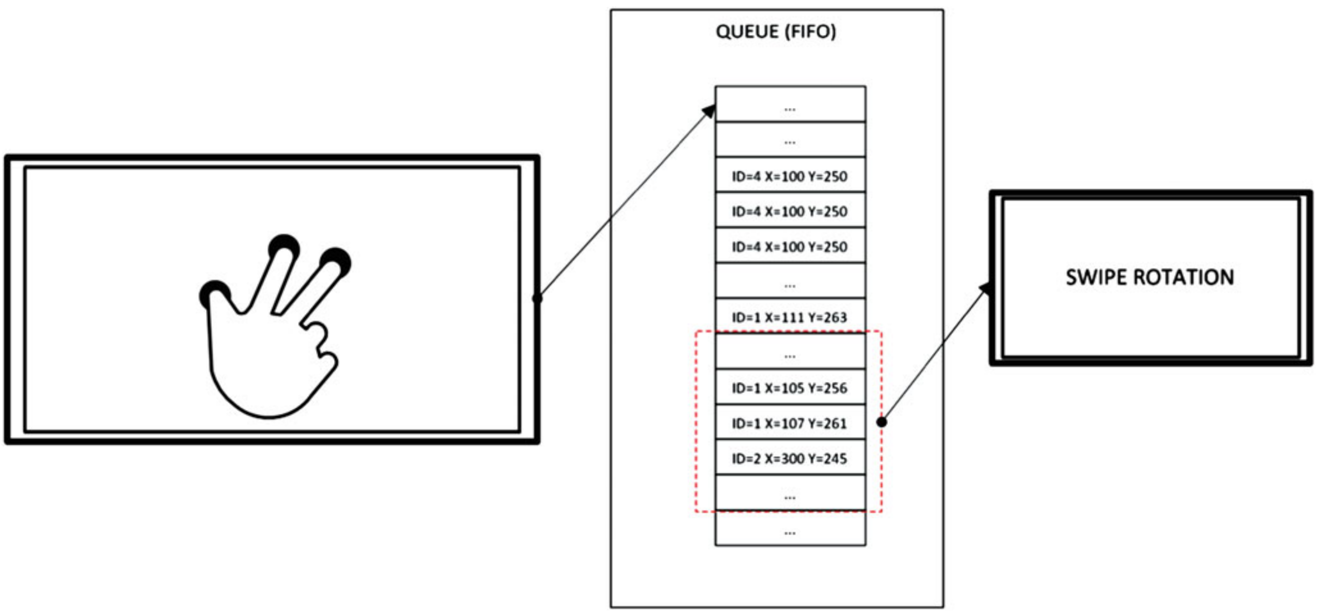

Fig. 2 Queue

the finger has been lifted, we have a state transition back to idle with the event up. Once the touch state has been reached, the decision must be made to identify it as either a tap (e.g., double tap, 2 finger tap) or a trace. (Note that the user will either be creating traces for a given gesture or a tap. It is our choice not to consider the tap as a gesture). If it is a trace, a transition follows to add this trace data to a thread-safe queue [27]. The queue is used to keep storing the traces while a specific window of data is processed. We can think of this window as a buffer. Once the queue is full, a transition will take place to the "process" state, where Algorithm 1 takes over.

Figure 2 gives more details about the queue and how we are using it. In the left side of the figure, we can see a user creating a three-finger gesture. One option for the user is to create a desired gesture and lift the hand. If this was the only case, then one can just process trace data as they are coming in with a small buffer. However, this brings us to the second case. Here the user can perform multiple gestures while leaving the hand in the screen. This is the reason that we need to have a window size long enough to detect a gesture while keeping the rest in the queue. Figure 2 shows this thread-safe queue to have a window size, for a given gesture.

Algorithm

Algorithm 1 detects swipe (translation), rotate, and pinch in/out (zoom in/out). If a system does not provide traces, one of the many clustering techniques available can be used to create them [28]. Because of the importance of a fast detection, any necessary pre-computations must be performed while the traces are added to the queue. This is why, when running the algorithm, is it expected to have the grip computed.

Our primary motivation is to lower the running time of the gesture detection in order to use it with demanding 3D applications. Therefore, the running time of the algorithm is as important as the complete utilization of all the resources available in the system. In this context, it is important to note that the gesture detection runs in its own thread. For more details about this multi-threaded approach, a C++ implementation can be found in [27] or a more detailed explanation with Java code can be found in The Art of Multiprocessor Programming [29].

Algorithm 1 starts by popping the buffer window in line 1. Because there are no clear initial and final snapshots, we assume that by popping the first half of the buffer and popping the rest of the buffer we can obtain an initial and final state of the traces. Because this was tested with off. line data, the data was already created with initial and final snapshots. Lines 2 and 3 assign each snapshot. Before we continue, we must define the variables grip, spread, trace, trace vector, angle rotation and traces.

Traces is a set that contains information for the path taken by each finger. In other words, for each finger, a set of properties is pre-computed, which is called **trace** in the algorithm. For example, the x and y coordinates is the average of a given trace, as shown in Eqs. 1 and 2 (for the y coordinate, replace the x for the y) already calculated per trace. Note that the variable *n* in the formulas refer to the total x,y points for a given trace. Because we are dividing the buffer into two snapshots, each snapshot has its own average. A **grip** is defined by the average of all points in each snapshot. A **trace vector** is defined as trace minus the grip, as shown in Algorithm 1 lines 12 through 15. The **spread** is given by lines 18–19 in Algorithm 1, which calculate the spread as the average difference between the grip point and the touch vector. Finally, the **angle rotation** is the average of the angle obtained by atan2 [30]. In other words, this is the angle between the final touch vector and the initial touch vector.

Finally, the chosen gesture is given by any of the three distance variables (swipeDistance, rotDistance, or zoomDistance) with the highest values found in Algorithm 1. The swipe distance is given by the spread of the first trace and the grip. The rotate distance is given by the arc length. This is the average angle obtained in line 20 and the radius of the swipe distance. Remember that atan2 [30] values range between ± π. In order to obtain the distance, the proper factor 2 must be multiplied as shown in Eq. 3. The zoom distance is given by the average final spread distance and the average initial spread distance.

Once everything is computed in the for loop, all we have left to do is to determine the correct gesture. The gesture detected is assigned according to the higj1est distance value of the swipe distance, rotation distance or zoom distance. Additional information can be obtained for specific detected gestures. For example, if the gesture detected is a zoom gesture, then additional information can be found, such as if the direction of the user is inward or outward. While the primary goal of the algorithm is to find the correct gesture, additional information is important to be precise about the gesture. Algorithm 1 concentrates in finding the gesture type.

Algorithm 1 GestureDetection

Require: TouchCount ¿ 0
1: $traces \leftarrow traceQueue.getWindow()$
2: $iTrace \leftarrow traces.getHalf()$
3: $fTrace \leftarrow traces.getHalf()$
4: $iGrip.x \leftarrow iTrace.getGrip.x$
5: $iGrip.y \leftarrow iTrace.getGrip.y$
6: $fGrip.x \leftarrow fTrace.getGrip.x$
7: $fGrip.y \leftarrow fTrace.getGrip.y$
8: $ivFirst.x \leftarrow iTrace[1].x - iGrip.x$
9: $ivFirst.y \leftarrow iTrace[1].y - iGrip.y$
10: $swipeDistance \leftarrow sqrt(ivFirst.x^2 + ivFirst.y^2)$
11: **for** $t = 1$ to $traces.Count$ **do**
12: $iv.x \leftarrow iTrace[t].x - iGrip.x$
13: $iv.y \leftarrow iTrace[t].y - iGrip.y$
14: $fv.x \leftarrow fTrace[t].x - fGrip.x$
15: $fv.y \leftarrow fTrace[t].y - fGrip.y$
16: $di \leftarrow sqrt(iv.x^2 + iv.y^2)$
17: $df \leftarrow sqrt(fv.x^2 + fv.y^2)$
18: $iSpread \leftarrow iSpread + di$
19: $fSpread \leftarrow fSpread + df$
20: $angle \leftarrow atan2(fv.y - iv.y, fv.x - iv.x)$
21: $rotAngle \leftarrow rotAngle + angle$
22: **end for**
23: $iSpread \leftarrow iSpread/traces.Count$
24: $fSpread \leftarrow fSpread/traces.Count$
25: $rotAngle \leftarrow rotAngle/traces.Count$
26: $zoomDistance \leftarrow fSpread - iSpread$
27: $rotDistance \leftarrow rotAngle/360.0 * 2 * \pi * swipeDistance$
28: **return** Gesture With Highest Distance

$$iTrace[id].x = \frac{1}{n/2} \sum_{i=0}^{\frac{n}{2}-1} trace[id][i].x \tag{1}$$

$$fTrace[id].x = \frac{1}{n/2} \sum_{i=\frac{n}{2}}^{n-1} trace[id][i].x \tag{2}$$

$$rot\ Distance = \frac{\Theta}{360} 2\pi r \tag{3}$$

Future Work

We believe that the combined approach of feature extraction and state machine for gesture detection provides a fast and easy-to-implement solution. In the quest of searching for different solutions, one can only hope to reach such elegant solution as the seminal work by Buxton [31]. Can we find a one-model-fits-all approach? This is a question that we hope to answer in the near future.

A follow up question that we would like to address in our future work is: Can we detect all possible multi-touch gestures with a combination of feature extraction and finite state machine in real time? We believe that this can be done. Our next phase will be to expand our work and test it in real time.

Conclusion

Multi-touch displays have become more widely used and are a standard of one of the de-facto NUI devices that will shape the post-WIMP era. In this paper, we have outlined some valuable previous contributions to the area of stroke and gesture recognition. This review of the literature provides a context for our approach and the reasoning behind our algorithm.

We proposed an algorithm and a set of concepts to allow gesture detection while using off-line data for multi-touch displays. This paper defined concepts such as grip, touch vector, trace and traces to allow the understanding of our algorithm. We explained how to implement Algorithm 1 with the emphasis on an efficient and easy to implement approach.

The next step in the development of our approach is to evaluate its efficiency using real-time data while adding more gestures. As already expressed, our end goal is to use fast gesture detection algorithms for high-demanding applications running in 3D environments.

Acknowledgments This work was sponsored by NSF grants HRD-0833093, and CNS-0959985. Mr. Francisco Ortega is the recipient of a GAANN fellowship, from the US Department of Education, at Florida International University.

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Model Driven Testing for Cloud Computing

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Abstract

In this paper, the authors present a proposal to support the creation of test cases for software systems under cloud computing environments. This approach is based on Model Driven Engineering (MDE). A Methodology and metamodels are proposed to support the generation of test cases. Specific metamodels for cloud computing environments are provided. Business models are created conform to UML (including profiles) and test cases are created conform to a metamodel that is independent testing platform. Both models are manipulated by model transformation that generates test cases for cloud computing environments. These metamodels are used in conjunction with the tool MT4MDE and SAMT4MDE for developing testing models. An illustrative example helps to understand the proposed approach.

Keywords

Model driven engineering • Model driven testing • Testing • Cloud computing

Introduction

Cloud computing refers to applications and services that are available on the network through virtualization and accessed via Internet [16]. The main difficulties encountered in cloud computing is the lack of interoperability between different platforms due the absence of standards between different clouds [18]. Moreover, the papers [19, 23, 2] detached the lack of standardization for testing softwares developed in the cloud computing platform.

So, an approach to support the automatic generation of test cases for cloud computing environments is required, ensuring quality and efficiency. Model transformation can support this approach contributing to automate the transfer of information between different levels of models, ensuring portability and interoperability. The Model Driven Engineering (MDE) contributes in the creation of interoperable applications. MDE provides a means for adapting legacy systems with new technologies and enables integration between different technologies [14]. Within the MDE, exists the Model-Driven Testing (MDT) to support the testing of software for reducing testing efforts during the course of developing software systems [17].

Overview

In this section, some technologies involved are presented, serving for the foundation of the proposed methodology based on MDE, providing the generation of test cases for cloud computing environments.

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_40,

Testing

The advance of technologies used in software systems and new applications of software systems had demanded more quality in the software development processes. To ensure this quality, the area of software testing is growing in recent years. The software testing can be considered one of the most onerous steps in the software development process [11].

In general, the software testing process has two distinct goals. The first goal is assure that the software meets the requirements. The second goal is to discover faults or defects in softwares that have incorrect behaviors or that do not comply with the requirement specification [15].

Model Driven Engineering

The Model-Driven Engineering (MDE) is an approach to support software development that focuses on creating models that describe the elements of a system [14, 24] and guide implementation. The automatic generation of test cases depends on the choice of suitable approach. Model-Driven Testing (MDT) constitutes a promising approach to support software testing.

Cloud Computing

Cloud computing offers a multi-layer architecture with shared resources [5]. The resources can be dynamically allocated according to a Service Level Agreement (SLA) and can be based on a "pay-per-used" business model to obtain cost-effectiveness and performance of the resources used [22].

Different types of cloud infrastructures can be deployed. This infrastructure can be called service models [16, 20]. The three main services are models: Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS).

SaaS and Service Oriented Architecture (SOA) are complementary. They have in common is the service model [20]. SOA is characterized as a paradigm of software architecture that defines the use of services to support the requirements of software users [6]. SOA is not a tool or framework to work. SOA can be considered as an approach for building software architectures. This architecture can bring many benefits [10] such as promoting reuse and ability to combine services to create new composite applications.

In cloud applications, SOA provides an architectural design to access various services through a flexible method. SOA supports the software evolution.

Thus, cloud applications become more user configurable thanks to SOA infrastructure [16].

Supporting Testing in Cloud Computing

Test support for cloud computing is a new way to test Web applications that use this environment. These tests seek to simulate real world environments through load testing and stress testing [7, 13]. There are several advantages when working with test for cloud computing [7]:

- Reduced costs because the infrastructure clouds can support networking and various machines for the test environment;
- Improve the efficiency of the tests, because it can reduce the time to build a test environment, such as machines, networks, operating system installation and installation of various testing tools;
- Allows performance test more realistic, because the infrastructure supports multiple virtualized machines.

An MDE Proposal for Generating Test Cases for the Cloud Computing Environment

Our proposal for software testing is based on MDE and supports the generation of test cases for cloud computing environments and provides a methodology and metamodels. Our approach aims to support interoperability between Cloud Computing platforms in the model level. Metamodels are designed to provide support for generating functional test cases and non-functional test cases such as stress and response time.

Figure 1 illustrates the metamodels and steps proposed for generating test cases for cloud computing. Circles with numbers have been added for better understanding of the sequence of steps within the process activities. Metamodels are proposed for the creation of platform independent test models (as number 1), supporting the choice of test cases that are generated and the types of tests criteria used in the input data represented in PIM.

Once platform independent testing model is created (step 2), a platform specific model is generated by model transformation (step 3). Then, this test model is transformed into source code that is conform to the PSM of a specific cloud platform through a model-to-text transformation, as shown in step 4 in Fig. 1.

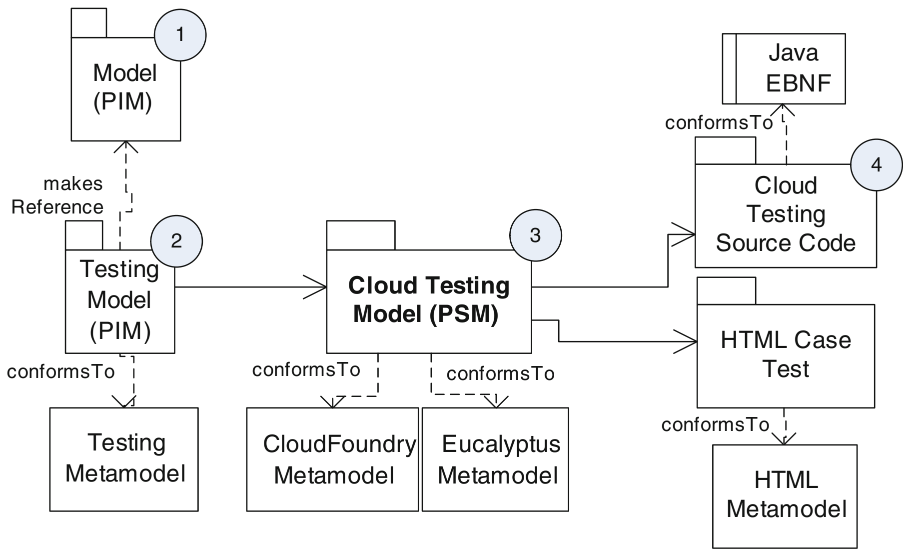

Fig. 1 Proposed approach to support testing in cloud computing

A Methodology to Support Testing in Cloud Computing

A methodology is presented in Fig. 2 and it is proposed to support the creation of test cases for systems based on cloud computing environments. The proposed methodology has the following steps: the creation of a business model as PIM, and utilization of model transformation for generating PSM and source code to a specific cloud computing environment.

Transformation definitions are described in a transformation language such as Atlas Transformation Language (ATL). In our proposal, a transformation definition is semi-automatically generated by the tool MT4MDE and SAMT4MDE [3, 9].

A Platform Independent Model (PIM) for testing is created by a software engineer. An algorithm assists in the choice of testing criteria used to create the test model. After the creation of the test model, Platform-Specific Models (PSMs) are generated through model transformations that has PIM as input. So, transformation definitions are applied for generating system source code and testing source code.

Metamodels

In MDE, metamodels are essential for creating models and transformation definitions are essential to move information from a model to another model [12]. In this paper, we present metamodels conceived to improve the quality of software testing for cloud computing.

1. *Platform Independent Metamodel for Testing: Testing Metamodel:* The platform independent metamodel is based on functional testing, integration testing, and some testing criteria of performance. The Metamodel Testing presents the following main elements: The TestType contains TestCriteria the ModuleTest the TestSuite, TestCase, the TestDate and IntegrationTest (Fig. 3).
2. *Cloud Testing Metamodel for CloudFoundry:* Cloud Foundry is an open service platform, designed by VMware [21], to provide services for users in building and deploying applications [4]. The Fig. 4 presents the Cloud Testing Metamodel for CloudFoundry. The proposed metamodel CloudFoundry was based on the metamodel xUnit work [8, 17], including the characteristics of the CloudFoundry platform.

An Illustrative Example

To demonstrate the functionality of the proposed approach, we present an illustrative example which aims develop test cases for a message system. This system use two Web services, a service message insert and search of service the stored message, as Fig. 5.

The test cases generated for this illustrative example was developed for CloudFoundry (functional tests) and for Eucalyptus Cloud (non-functional tests). In other words, the same application will be developed to two different clouds, CloudFoundry and Eucalyptus. So, we demonstrate the interoperability achieved by the models developed this works.

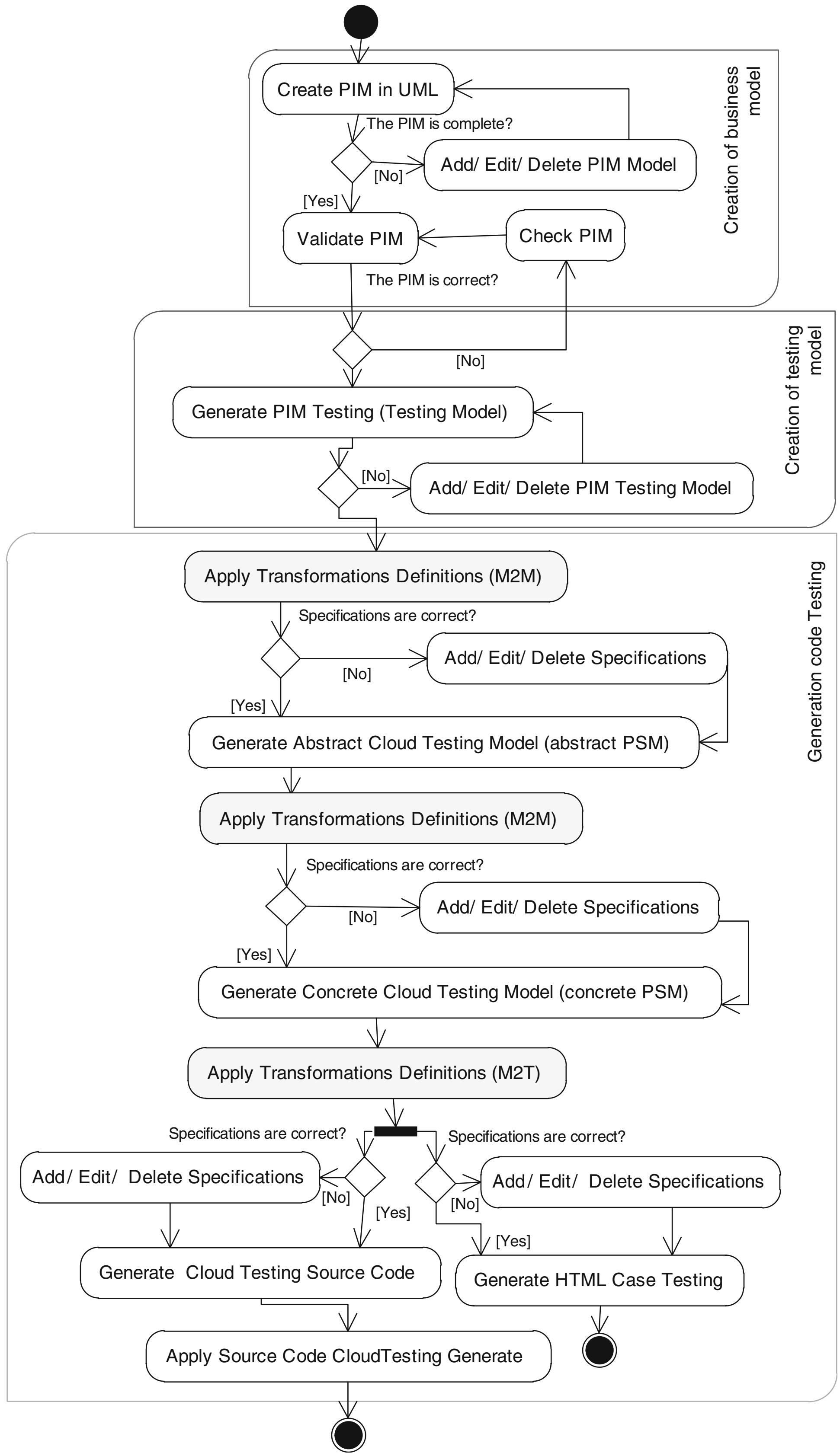

Fig. 2 Proposed approach to support testing in cloud computing

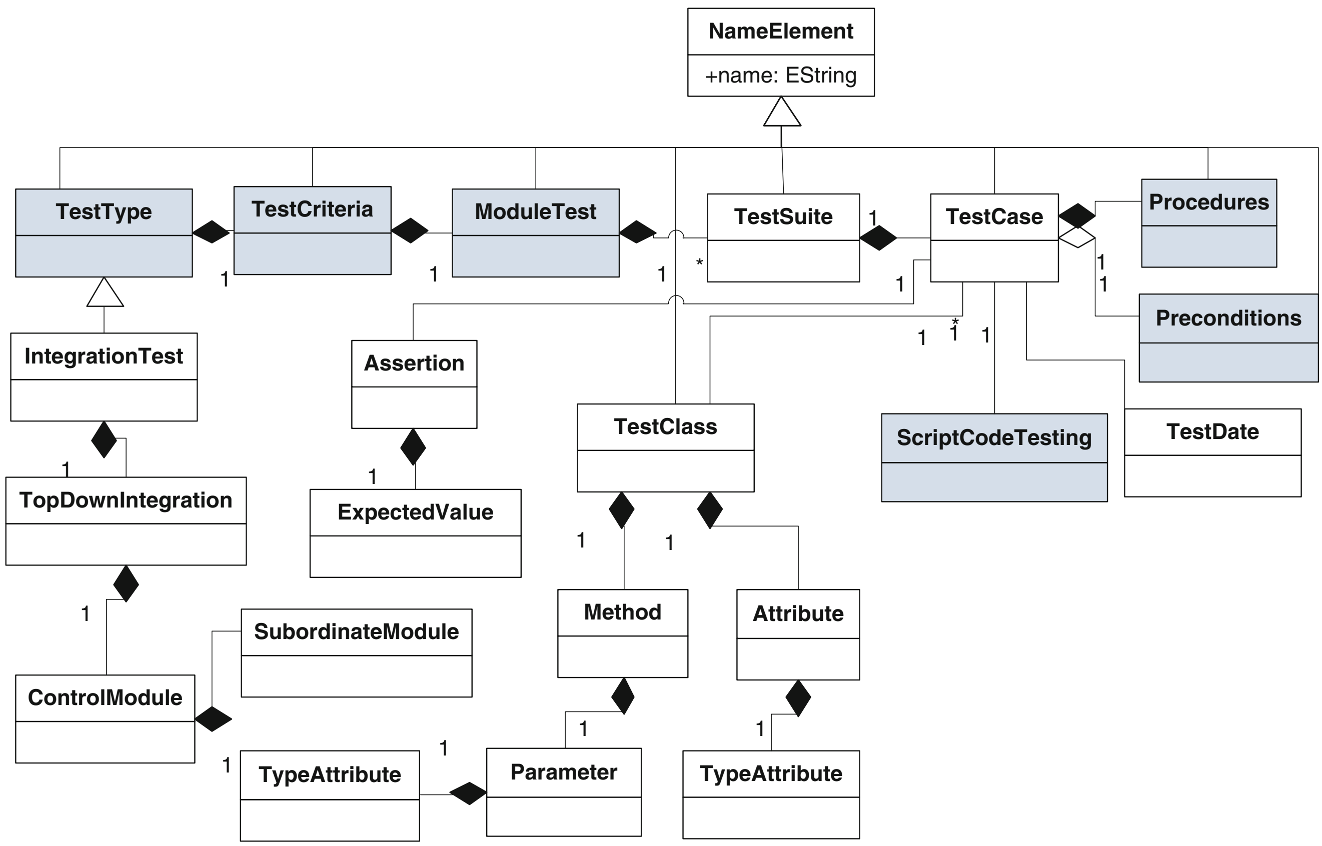

Fig. 3 Testing metamodel

Platform Independent Model (PIM)

Initially, a business model is created (i.e. PIM) according to UML class diagram (step 1, in Fig. 1). Figure 6 presents the business model for this illustrative example.

Testing Model (PIM)

Once the business model was created, a testing model is proposed including testing criterias that are modeled conform to metamodels stored in a model repository.

The testing model (PIM) was created according to TestingMetamodel metamodel and it is presented in Fig. 7. In this model, two test cases are presented. The first test case refers to the method MessageInclude and second test case refers to the method MessageList.

PSM

In this illustrative example, we propose generate the PSM in CloudFoundry. For this purpose we provide a CloudFoundry Metamodel. A transformation definitions in ATL (fragment)

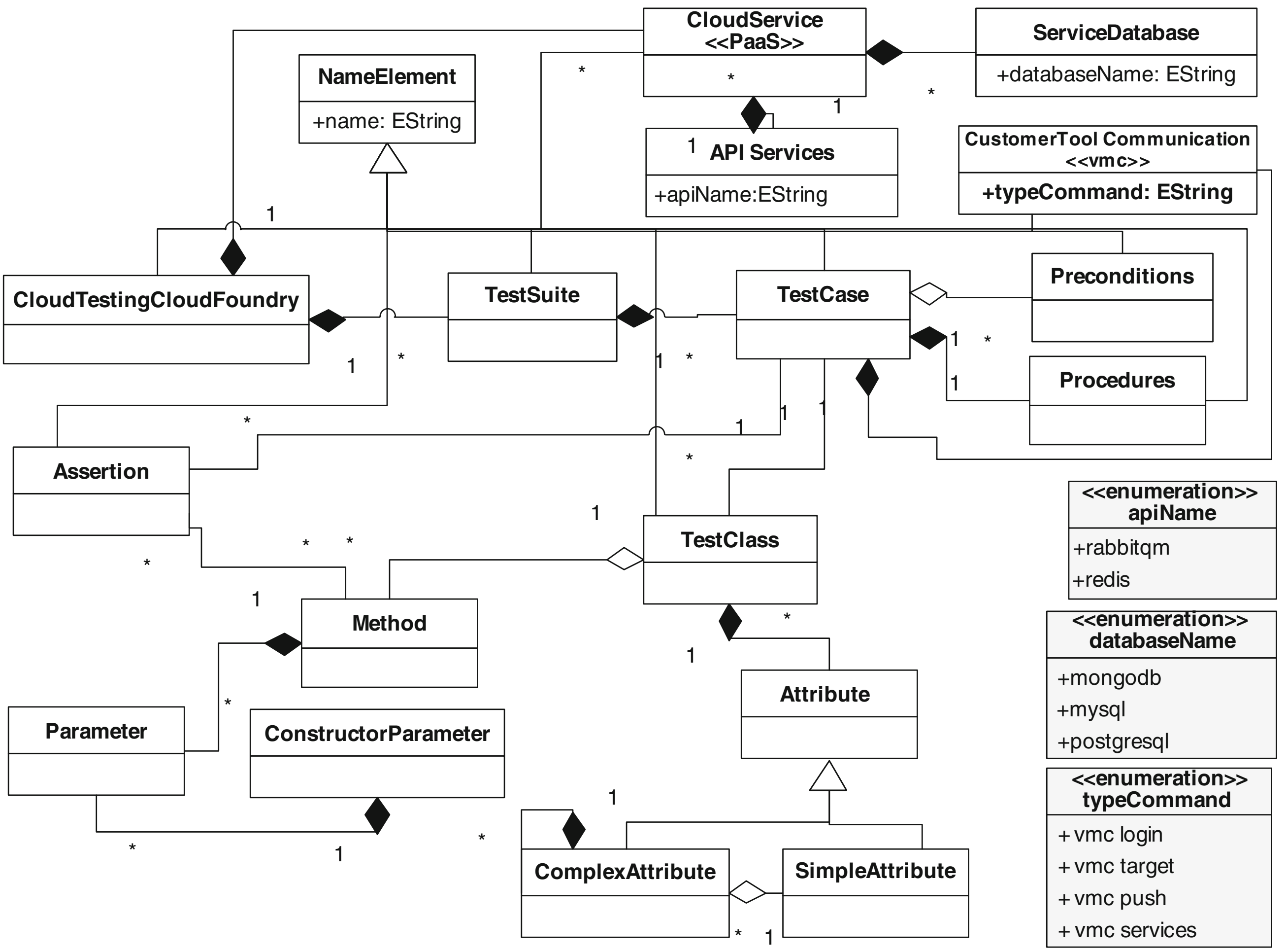

Fig. 4 Cloud testing metamodel: cloudfoundry

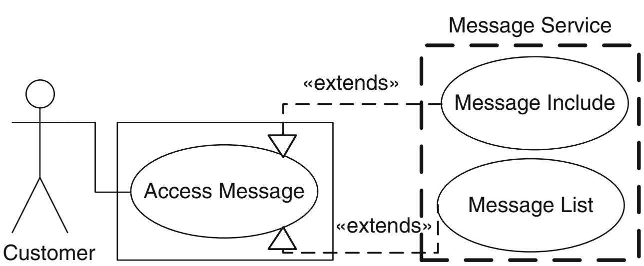

Fig. 5 Illustrative example: use case diagram

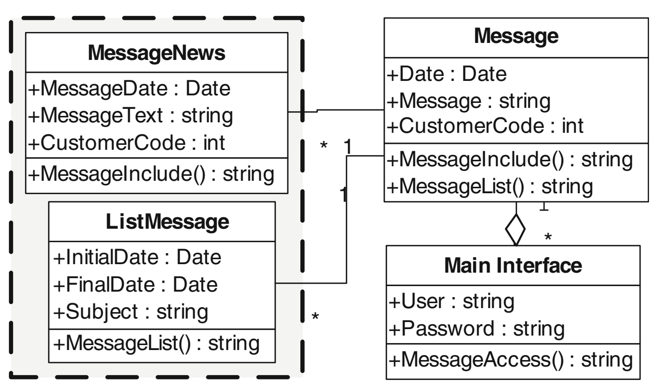

Fig. 6 Illustrative example: PIM in UML

for generating a CloudFoundry model is presented in Listing 1.

List. 1 ATL Code for generating CloudFoundry PSM

```
module cloudtesting2cloudtestingcloudfoundry;
create OUT:cloudtestingcloudfoundry from IN:cloudtesting;

rule
customerToolCommunication12CustomerToolCommunication{
        from customertoolcommunication1:
        cloudtesting!CustomerToolCommunication1
        to customertoolcommunication:
        cloudtestingcloudfoundry!CustomerToolCommunication
        (
                name<- customertoolcommunication1.name
        )
}


rule CloudServices12CloudService{
        from cloudservices1:cloudtesting!CloudServices1
        to
cloudservice:cloudtestingcloudfoundry!CloudService
        (
                name<- cloudservices1.typeService,
                cloudAPI<- cloudservices1.CloudServicesAPI
        )
}


rule APIServices12APIServices{
        from apiservices1:loudtesting!APIServices1
        to apiservices:cloudtestingcloudfoundry!APIServices
        (
                apiName<- apiservices1.name,
                APICloud<- apiservices1.APIServicesCloud
        )
}


rule TestSuite12TestSuite{
        from testsuite1:cloudtesting!TestSuite1
        to testsuite:cloudtestingcloudfoundry!TestSuite
        (
                name<- testsuite1.name,
                testCaseCount<- testsuite1.testCaseCount,
                testSuiteTestCase<- testsuite1.testSuiteCase
        )
}


rule TestCase12TestCase{
        from testcase1:cloudtesting!TestCase1
        to testcase:cloudtestingcloudfoundry!TestCase
        (
                name<- testcase1.name,
                testCaseTestSuite<- testcase1.testCaseSuite,
                testCaseProcedure<-
testcase1.testCaseProcedures,
                testCasePrecoditions<-
testcase1.testCasePreconditions,
                testCaseTestClass<-
testcase1.testCaseTestClass
        )
}
```

PSM to Source Code

In the last step, testing code are generated according to EBNF Java language [1].

Listing 2 presents the transformation definition written in ATL to transform CloudFoundry PSM in testing source code.

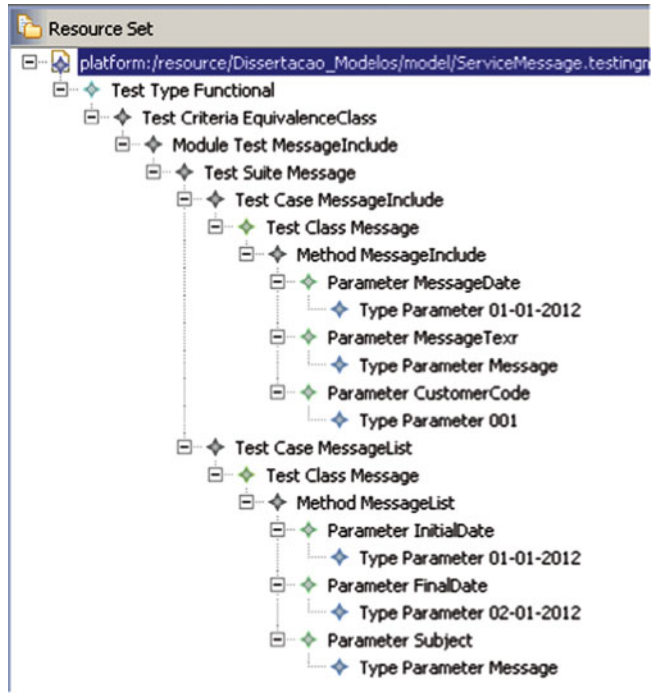

Fig. 7 Testing model: PIM

List. 2 Fragment ATL code for generating jUnit code from CloudFoundry PSM

```
  helper context cloudTestingCloudFoundry!Method def:
callsMethod(): String =
  'new '+ self.freeParameter + '().'
  if self.methodParameter->isEmpty() then '' else
  self.methodParameter->iterate( i ; acc:String=''| acc +
  if acc='' then ''  else ','
  endif + i.name) endif +')';

  helper context cloudTestingCloudFoundry!Assertion def:
generateAssertionType() : String =
  '\n' + '\t\t'+ self.getNameAssertion() +
  '(' + self.expectedValue + ', '+
self.assertionMethod.callsMethod() + ');';
```

Listing 3 shows the testing code (fragment) generated by transformation definition that takes as input the PSM and generates a testing source code according to CloudFoundry platform.

List. 3 Code Testing in jUnit

```
  public class MessageList extends
junit.framework.TestCase{

    @Test
    public void AssertionTestMessageList(){

   assertEquals(01-01-2012, new MessageList().());
   }

   @Test
    public void AssertionTestMessageList2(){

   assertEquals(Message, new MessageList().());}

   }
```

The testing source code is written in Java language and it aims to provide the functional testing.

Conclusions and Future Directions

Model-Driven Testing provides support to test the source code generated by model transformations. In this research work, a methodology and some metamodels were proposed for generating test cases for systems based on cloud computing environments. Testing metamodels introduced specific testing criterias. An illustrative example was presented to demonstrate our proposed approach. In the future, we aim to improve our approach and introduce another cloud computing environments.

Acknowledgment The work described in this paper is supported by CAPES, FAPEMA (through the grant APP-00944/09) and CNPq (through the grant 560231/2010-5).

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Implementing a Sensor Fusion Algorithm for 3D Orientation Detection with Inertial/Magnetic Sensors

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Abstract

In this paper a sensor fusion algorithm is developed and implemented for detecting orientation in three dimensions. Tri-axis MEMS inertial sensors and tri-axis magnetometer outputs are used as input to the fusion system. A Kalman filter is designed to compensate the inertial sensors errors by combining accelerometer and gyroscope data. A tilt compensation unit is designed to calculate the heading of the system.

Keywords

Sensors • 3D • Detection • Algorithms • Filters

Introduction

Orientation tracking has a wide range of applications including military, surgical aid, navigation systems, mobile robots, gaming, virtual reality and gesture recognition [1, 2]. So far, orientation detections are mostly done by using "externally referenced" [3] motion sensing technologies, such as video, radar, infrared or acoustic tracking.

Although these methods achieve good results in an indoor environment, they suffer from some limitations, like shadows, light interruptions, distance limitations and interference [4, 5].

An alternative approach is to use inertial sensors. Inertial sensors detect physical quantities of the moving object regardless of external references, environment lighting or friction. This detected movement is directly related to the object that has the sensors attached. Furthermore, inertial sensors are self-contained technologies, which do not need external devices, like cameras or emitters. These sensors have been used in submarines, spacecraft and aircrafts for many years [6].

Micro-Electro-Mechanical-System (MEMS) based inertial sensors have emerged during the last decade. Due to their miniature size, low power consumption, and light weight [7], the use of inertial MEMS sensors has developed rapidly in recent years.

In this paper, an algorithm is proposed to detect orientation in three dimensions. An inertial measurement unit (IMU) is composed of a tri-axis gyroscope, a tri-axis accelerometer, and a tri-axis magnetometer. A Kalman filter is implemented to yield a reliable estimate of the orientation. Tilt compensation is applied to compensate the tilt error present in the raw measurement.

Data Acquisition

The IMU system we utilized is composed of a tri-axis gyroscope, a tri-axis accelerometer and a tri-axis magnetometer. The sampling rate is 8.96 samples per second. The gyroscope resolution is 16 bits and the sensitivity is 0.007°/s/digit. The accelerometer sensitivity is 0.00024 g/digit. Raw data were acquired while the sensors were stationary on the desk. In Fig. 1, the raw data extracted from sensors are shown.

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_41,

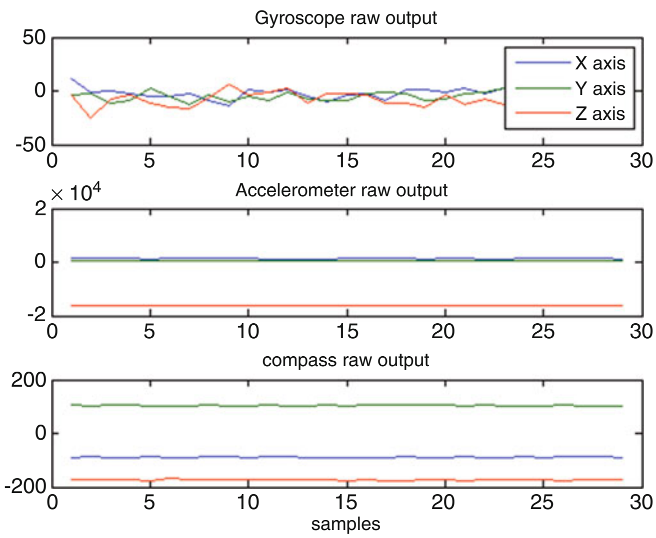

Fig. 1 Raw data

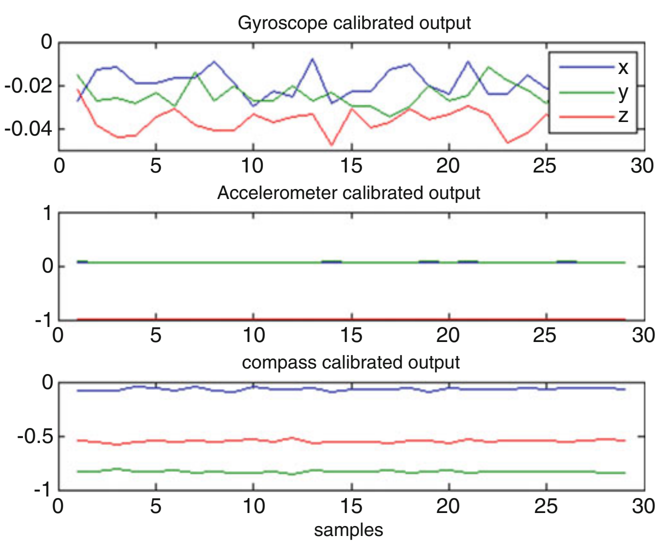

Fig. 2 Calibrated data

The raw data should not be used, as they need to be calibrated. To calibrate these data, scale and bias must be taken into account. The bias represents how far the center of sensor data is from zero. The scale means how much larger the range of data from the sensor is than the real values of the physical quantity.

Figure 2 presents the calibrated data from the gyroscope, the accelerometer and the magnetometer respectively. It can be observed that in the accelerometer calibrated data, X and Y axes are approximately zero and the Z-axis is -1. The axes X and Y are zero because there is no acceleration in these axes. In fact, the only acceleration present is the earth's gravity, which is along the Z-axis pointing downward. This is the reason for measuring a negative number in the Z-axis.

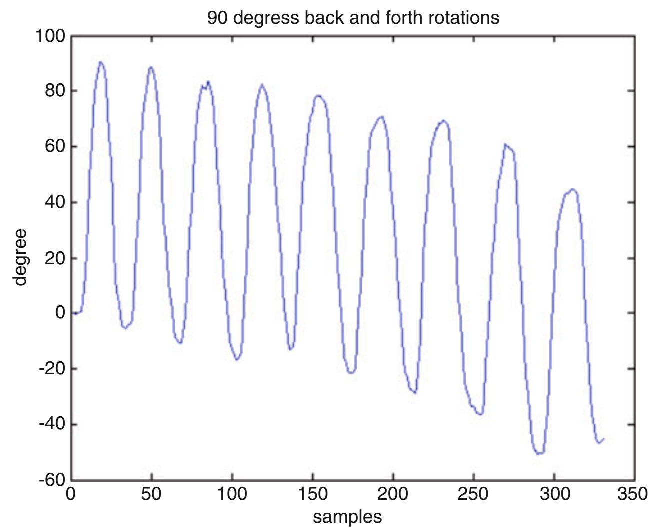

Fig. 3 Drifting rotation angle calculated by the gyroscope integration

The hardware was stationary when the data were recorded and no rotational movement was applied to the system. Therefore, the gyroscope did not record a rate of rotation. The fluctuations which are seen are random noise. This noise is inseparable from the gyroscope data; it will cause drift in the rotational angle, which is obtained based on the gyroscope's data.

Method

MEMS gyroscopes use the Coriolis acceleration effect on a vibrating mass to detect angular rotation. The gyroscope measures the angular velocity, which is proportional to the rate of rotation. They respond quickly and accurately and the rotation can be computed by time-integrating the gyroscope output. Figure 3 depicts the rotational angle, obtained by the trapezoidal integration from the gyroscope signal, for multiple 90° back and forth rotations.

The trapezoidal integration method [8] is shown in Eq. (1), for f(x) between interval a and b.

$$\int_a^b f(x)dx = (b-a)f(a) + \frac{1}{2}(b-a)[f(b) - f(a)] \tag{1}$$

The computed result drifts over time and after approximately 30 s it drifts down about 50°. The explanation for this phenomenon is that the integration accumulates the noise and offsets over time and turns them into the drift, which yields unacceptable results.

In fact, the integration result is less noisy than the gyroscope signal but there is more drift present. However one good aspect of the gyroscope is that it is not affected by earth's gravity.

Accelerometers measure acceleration based on the forces associated with the Newton's second law. The problem with accelerometers is that they measure both acceleration due to the device's linear movement and acceleration due to earth's gravity, which is pointing toward the earth. Since it cannot distinguish between these two accelerations, there is a need to separate gravity and motion acceleration by filtering. Filtering makes the response sluggish and it is the reason why the accelerometer has to be processed with information from the gyroscope.

By utilizing the accelerometer output, rotation around the X- axis (roll) and around the Y-axis (pitch) can be calculated. If Accel_X, Accel_Y, and Accel_Z are accelerometer measurements in the X-, Y- and Z-axes respectively, Eqs. (2) and (3) show how to calculate the pitch and roll angles:

$$\text{Pitch} = \arctan\left(\frac{\text{Accel\_X}}{(\text{Accel\_X})^2 + (\text{Accel\_Z})^2}\right) \quad (2)$$

$$\text{Roll} = \arctan\left(\frac{\text{Accel\_Y}}{(\text{Accel\_Y})^2 + (\text{Accel\_Z})^2}\right) \quad (3)$$

These equations provide angles in radians and they can be converted to degrees later. Figure 4 presents the rotation angle, which is computed by using the accelerometer signal. Despite recording this signal in a much longer interval, contrary to Fig. 3, no drift is observed in Fig. 4, but it is noisier.

In order to measure rotation around the Z-axis (yaw), the other sensors need to be incorporated with the accelerometer.

It has now been observed that neither the accelerometer nor the gyroscope provides accurate rotation measurements alone. This is the reason to implement a sensor fusion algorithm to compensate for the weakness of each sensor by utilizing other sensors.

System Configuration

The applied sensor fusion system is depicted in Fig. 5. The calibrated accelerometer signal is used to obtain roll* and pitch* by Eqs. (2) and (3). Roll* and pitch* are noisy calculations and the algorithm combines them with the gyroscope signal through a Kalman filter to acquire clean

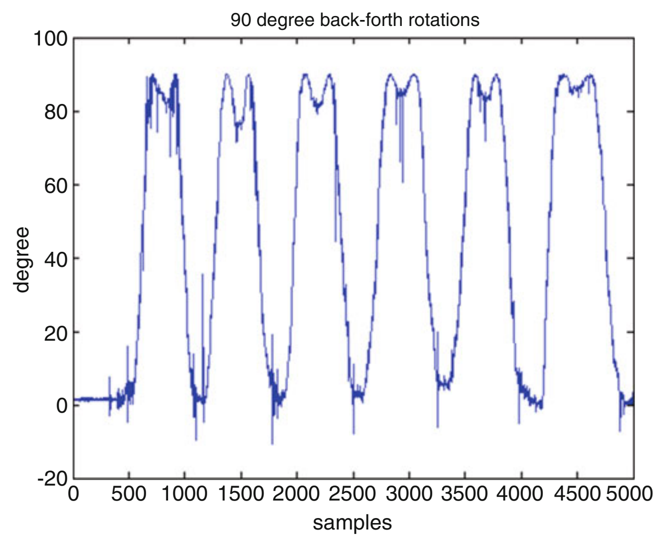

Fig. 4 Noisy rotation angle calculated by the accelerometer

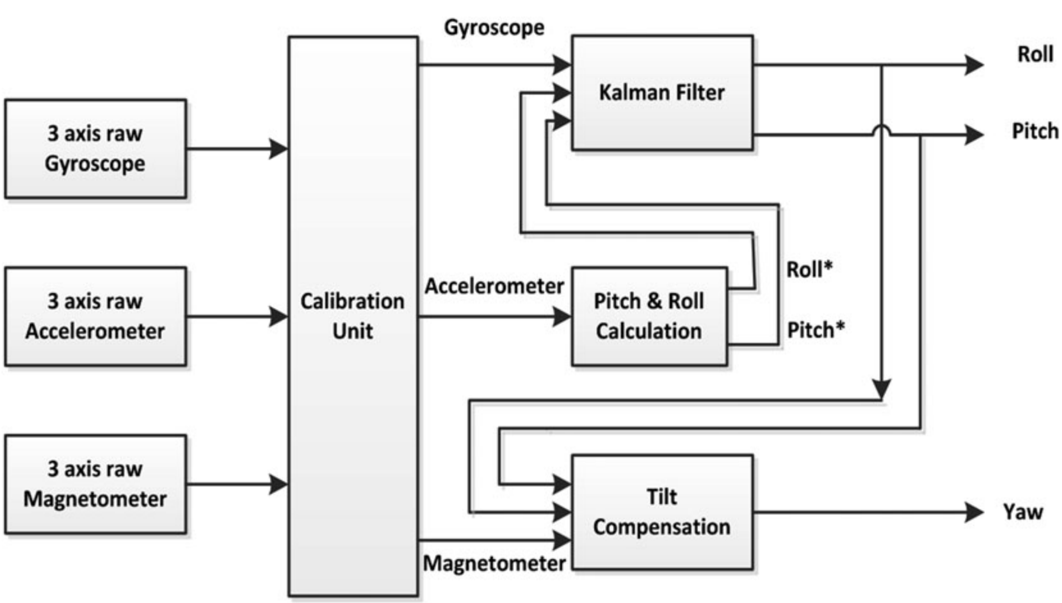

Fig. 5 System structure

and not-drifting roll and pitch angles. On other hand, a tilt compensation unit is implemented, which uses a magnetometer signal in combination with roll and pitch to calculate the challenging yaw rotation.

Kalman Filter

Kalman filtering is a recursive algorithm which is theoretically ideal for fusion processing of noisy data. Implementation of the Kalman filter calls for knowledge of the physical properties of the system. Kalman filter estimates the state of system at a time (t) by using the state of system at time (t−1). The system should be described in a state space form, like the following:

$$x_{k+1} = Ax_k + w_k \tag{4}$$

$$z_k = Hx_k + v_k \tag{5}$$

Where; x_k is the state vector at time k, A is the state transition matrix, w_k is the state transition noise, z_k is measurement of x at time k, H is the observation matrix and v_k is the measurement noise. State variables are the physical quantities of the system like velocity, position, etc.

Matrix A describes how the system changes with time and matrix H represents the relationship between the state variable and the measurement. In our Kalman filter the input vector x, and A and H are:

$$\mathrm{x} = \begin{bmatrix} \omega \\ \varphi \end{bmatrix} \tag{6}$$

$$\mathrm{A} = \begin{bmatrix} 1 & -\Delta \mathrm{t} \\ 0 & 1 \end{bmatrix} \tag{7}$$

$$\mathrm{H} = [1 \quad 0] \tag{8}$$

Where ω is the angular velocity from the gyroscope, and φ is the rotation angle, which is calculated by the accelerometer signal. To implement the Kalman filter, the steps in algorithm 1 should be executed [10]. The A, H, Q and R should be calculated before implementing the filter. Q and R are covariance matrices of w_k and w_k respectively, which are diagonal matrices. Z_k is the system measurement vector and $\hat{x}_k$ is the filter output.

Algorithm 1

1. Set initial values,

$$P_0 = 0, \ \ \hat{x}_0 = 0$$

2. State prediction; the superscript ‘’means predicted value. This step uses the state from the previous time point to estimate the state at the current time point:

$$\hat{x}_k^- = A\hat{x}_{k-1}$$

3. Error covariance prediction; this step uses the error covariance from the previous time point to estimate the error covariance at the current time point:

$$P_k^- = AP_{k-1}A^T + Q$$

4. Kalman gain computation; H and R are computed outside the filter, and P_k^- comes from the previous step. Kalman gain is the weight used for the computation of the estimate and it updates for each time step based on error covariance:

$$K_k = P_k^- H^T \left(HP_k^- H^T + R \right)^{-1}$$

5. Estimate computation; in this step, the algorithm compensates the difference between measurement and prediction. This is the output of the filter:

$$\hat{x}_k = \hat{x}_k^- + K_k H^T \left(z_k - H\hat{x}_k^- \right)$$

6. Error covariance computation; error covariance indicates the degree of estimation accuracy. Larger P_k shows bigger error in estimation:

$$P_k = P_k^- - K_k H P_k^-$$

7. Loop to step 2;

Tilt Compensation

As mentioned earlier, computing the rotation around the Z-axis is challenging (the Z-axis is perpendicular to the earth’s surface). This angle is also called the heading or azimuth. If the gyroscope is used to calculate the heading, not only is the drift problem encountered, but the initial heading must be known [11].

The earth’s magnetic field is parallel to the earth’s surface. Therefore, while the tri-axis magnetometer is parallel with the earth’s surface, it can measure the heading accurately through the direction of the earth’s magnetic field [12]. However, in most applications, the magnetometer is attached to the object and it moves with the object and goes out of the horizontal plane.

By tilting the magnetometer, the direction of axial sensitivity will change [13]. Consequently, it will be difficult to measure the heading. Depending on how much the magnetometer tilts, different amounts of error appear in the calculations.

The tilt compensation process maps the magnetometer data to the horizontal plane and provides the accurate heading calculation regardless of the position of the magnetometer.

The roll and pitch angles are utilized in combination with magnetometer data to correct the tilt error, regardless of the magnetometer's position.

As Fig. 5 shows, the roll and pitch angles come from the output of the Kalman filter.

If m_x, m_y, and m_z are calibrated and normalized magnetometer outputs, and α, β and γ present roll, pitch and yaw respectively, the heading is calculated by Eq. (9). Equations (7) and (8) are used to transform the magnetometer reading to the horizontal plane. When magnetometer data is mapped to the horizontal plane, Eq. (9) obtains a reliable calculation.

$$\begin{aligned} XH = m_x \cos(\beta) + m_y \sin(\beta)\sin(\alpha) \\ + m_z \sin(\beta)\cos(\alpha) \end{aligned} \tag{7}$$

$$YH = m_y \cos(\alpha) + m_z \sin(\alpha) \tag{8}$$

$$\gamma = \operatorname{atan2}\left(\frac{-YH}{XH}\right) \tag{9}$$

The difference between the regular inverse tangent and the MATLAB's command "atan2" is that the first one returns the results in the range of [−π/2, π/2], while "atan2" calculates the results in the range of [−π, π].

Experimental Results

In order to evaluate the performance of the proposed system, some experiments were performed to measure the Euler orientation.

Initially, the hardware was manually moved back and forth in the horizontal plane. It was observed that roll and pitch angles remained constant during this movement. A small fluctuation has been observed in the yaw angles measured, which is because of hand unsteadiness while the hardware was moved. This shows the system can detect even small fluctuations.

The experiment was repeated in both planes, which are perpendicular to the X-axis and perpendicular to the Y-axis as well. Observations proved that the system could track both roll and pitch angles accurately. In both roll and pitch movements, the hand fluctuations can be observed.

The Kalman filter was designed to estimate the orientation. To evaluate the performance of the Kalman filter, an experiment was carried out. Back and forth movements around X-axis were applied to the hardware. The roll angle was obtained by integrating the gyroscope output and then it

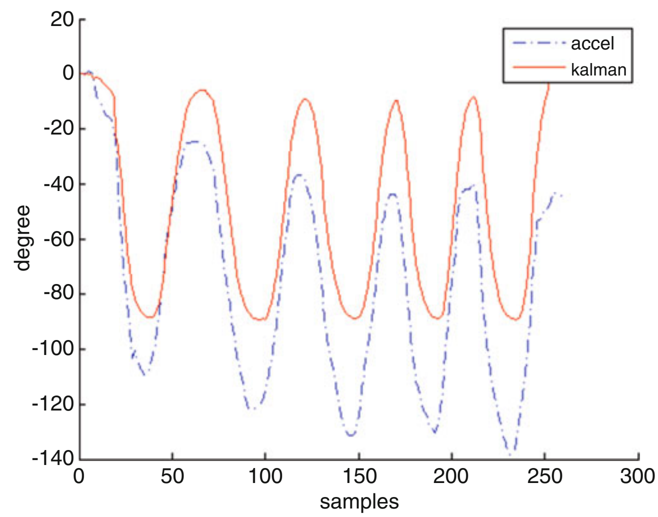

Fig. 6 Comparison between the Kalman filter's output and the gyroscope integration result

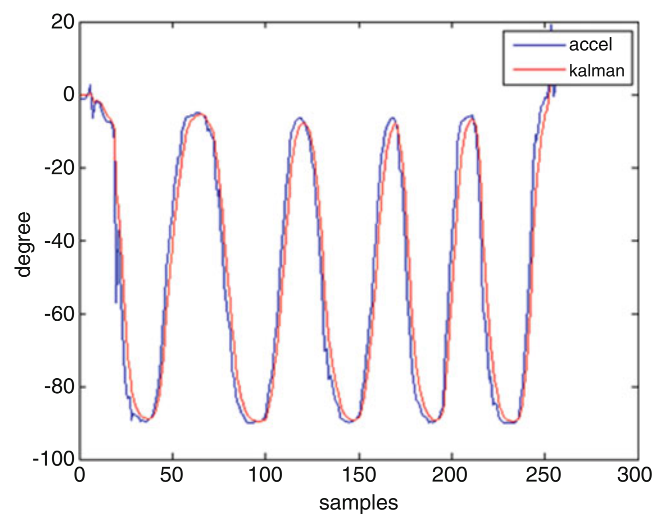

Fig. 7 Comparison between Kalman filter output and the accelerometer result

was compared with the result from the Kalman filter. The results are depicted in Fig. 6.

The dashed line shows the results come from the gyroscope integration by the trapezoidal integration method and the solid line shows the output from the Kalman filter. Noticeable down-drift is clearly seen in the result from integration while this drift is eliminated in the Kalman filter results.

Evaluation of the performance of the Kalman filter continued by comparing the rotation angle from the accelerometer with the Kalman filter output. In Fig. 7, the red solid line presents the filter output and the blue solid line is the angle calculated by the accelerometer output. It is clearly observed that all fluctuations, seen in the accelerometer output, are eliminated successfully by the filter.

Conclusion

In this paper, a method was proposed to detect the orientation in three dimensions by utilizing micro-electromechanical sensors.

An efficient algorithm was proposed to deal with the limitation of inertial sensors based on the Kalman filter implementation. Heading compensation is applied to the system to provide accurate orientation around the Z-axis in any position. The experimental results confirmed the appropriate performance of the proposed algorithm.

Our next step will be expanding the algorithm such that it can measure the position in three dimensions.

Acknowledgments This work was sponsored in part by NFS grants HRD-0833093, and CNS-0959985.

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Introducing Problem-Based Learning in a Joint Masters Degree: Offshoring Information Technologies

Vincent Ribaud and Philippe Saliou

Abstract

A young offshore software industry has grown up in Morocco. The University of Brest has set up a network of major software companies and Moroccan universities, providing two mobility schemes towards France. Both schemes include a final internship on the French side of global companies, with pre-employment on the Moroccan side—a successful internship being the key that opens the door to recruitment. Student heterogeneity, and student reluctance to move towards a professional attitude are important barriers to employability. Hence, we redesigned a significant proportion of our technical courses to use a problem-based learning (PBL) approach. The PBL approach is illustrated through drawing parallels with the production of a TV series. Three aspects of the approach are presented: (1) set-up of the studio in which sessions are run, i.e. a real software project, its work products and its software development environment; (2) pre-production tasks including the screenwriting of problem-based learning scenarios and the procurement of input artefacts; and (3) acting, i.e. students' interpretation of characters (roles) and teacher direction.

Keywords

Student employability • Global software development • Problem-based learning

Introduction

The growth of Global Software Development has impacted the informatics education system, and universities are now offering specialized courses or entire programmes dedicated to Global Software Development/Global Software Engineering (GSD/GSE) [1–4]. The young Moroccan offshore industry has rapidly grown up as an attempt by French software companies to satisfy their clients' desire to offshore software projects. The Moroccan government has completed several initiatives aimed at fostering offshore industry. With regard to IT education, government funding has helped start new programmes called "Masters in Offshoring" at almost every Moroccan university. In 2007, an informatics teaching network was set up, comprising Moroccan and French universities. Moroccan and French stakeholders agreed to our university's proposal to act as a kind of placement agency providing some students with an internship in France. Ensuring graduates will return to the country of origin (Morocco) was seen as a crucial issue, and one that can only be guaranteed by strong institutional governance of each student's mobility. Recently, we replaced this mobility scheme with the possibility of basing the final year of study in France, leading to the award of a double Masters degree—Moroccan and French. The whole programme is called Offshoring Information Technologies (*Offshoring des Technologies de l'Information—OTI*). The programme involves major industrial players in offshore development: Logica, Capgemini, Atosscas well as nine Moroccan state universities.

We introduced a Problem-Based Learning (PBL) approach within some of the programme courses, mainly in

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_42,

an attempt to resolve two problems: heterogeneity of knowledge and skills between students, and reluctance on the part of certain students to transition from a passive learning attitude to one that is active. General issues are discussed in section "Issues Analysis", and the OTI programme itself is described in section "Description of the Programme". Section "Problem-Based Learning" presents an introduction to PBL, the practicum in which it is run, the screenwriting of problem-based learning scenarios and procurement of input artefacts, and student interpretation of roles directed by teachers. We finish with a brief conclusion.

Issues Analysis

Governmental Issues

In 2008, Gartner Research published a report on the Analysis of Morocco as an Offshore Location [5]. This report pointed out that Morocco is an attractive 'nearshore' alternative for Europe, and that several established companies have nearshore centres in Morocco. They noted also that Morocco has yet to provide a clean and democratic environment, although it is making progress in this area. In order to foster the development of Morocco as an offshore country, the Moroccan government has implemented several initiatives to promote the Information and Communication Technology (ICT) industry—including, in December 2006, an emergence plan entitled "10,000 ingénieurs" (10,000 engineers). This plan aimed to provide the software development market with 10,000 novice engineers per year. Although in 2006, just 4,000 such novices had graduated, by 2010, they numbered 10,600—including 3,700 Masters graduates issuing from state universities. The government's current objective is to train 15,000 engineers a year from 2015, and 25,000 from 2020.

High Education Issues

The Mediterranean Office for Youth—MOY (http://www.officemediterraneendelajeunesse.org/en) was recently established in recognition of the fact that circular migration for educational purposes is a decisive factor in the development of wealth, intercultural exchange, and mutual understanding in the Mediterranean region. The MOY is operating in 14 countries around the Mediterranean, and is labelling higher education training programmes of excellence corresponding to fields of Mediterranean interest. The MOY label is awarded to Masters and PhD programmes meeting the conditions and criteria set by MOY for the purposes of facilitating student mobility in disciplines identified as priorities for the development of the Mediterranean region, and promoting the employment of young people in their country of origin. We responded to the first call for proposals for MOY labelling, and our programme—along with 41 others—was selected. It is the only joint Masters in information technologies/software engineering.

Companies' Issues

The notion of distance is considered a major factor impacting Global Software Development (GSD) [4, 6]. GSD teams are usually made up of members from different countries, speaking different languages and with different managerial traditions. This is called the socio-cultural distance. Almost all initiatives indented to reduce socio-cultural distance rely on a long period of immersion in the foreign culture.

When we started the programme in 2007, the major players in the Moroccan offshore software industry (Logica, AtoS, Capgemini, and HP-CDG) asked us to provide facilities that would enable Moroccan and French team members to spend time together in order to help French and Moroccan teammates "rub up against one another". We made a pragmatic response offering prospective young Moroccan employees the opportunity of a stay in a French company that is long enough to understand how French teams behave, professionally.

GSD Education Programme

Few universities offer entire programmes intended to prepare IT engineers to work in a multicultural environment. Detroit Mercy University has offered such a course for more than 20 years now: International Studies in Software Engineering Program (ISSE). The main course of action is to immerse students in foreign culture—which is also our principal method. Our programme differs in that we offer Moroccan students an experience in a foreign university and in a foreign business (the French side of the company linked with the potential Moroccan employer).

In Europe, we are aware of two European Masters programmes in Global Software Engineering, which are named: European Master on Software Engineering (EMSE, http://emse.fi.upm.es/) and Global Software Engineering European Master (GSEEM, http://www.gseem.eu/). Both of these use a 1-year mobility scheme, with the first year completed at the university of origin and the second at a foreign university. Like our proposal, this is a 1-year foreign immersion leading to a double Masters degree. Both programmes are research-oriented. Compared to existing programmes, the most distinctive feature of our programme lies in its strong career orientation, since it is designed to gain an initial professional experience in France that is intended to lead to employment in Morocco.

Description of the Programme

Fundamental Principles

Professional integration issues have been at the heart of the programme ever since it was started, back in 2007. Strict control of mobility is required. The French government's priority is to prevent illegal immigration, while Morocco wants to hang on to its most talented people. The partners have therefore agreed:

1. *A founding principle:* Acquire a first experience in France and then mobilize the skills gained, for the benefit of Morocco's economic development.
2. *Centralized co-ordination of mobility and employability:* This co-ordination is supported by the University of Brest, which acts as a hub connecting Moroccan universities, Moroccan students, future Moroccan employers and French companies working in offshore software development. The university also co-ordinates the various academic, administrative and legal procedures.

Terms of Mobility

The OTI programme includes two mobility schemes. Since 2007–2008, the scheme called "Stage en France avec une pré-embauche au Maroc" (SFM), *Internship in France with pre-employment in Morocco*, provides mobility over one semester. In 2010, we replaced this scheme with another, based on mobility over 1 year. This is a joint Masters degree from the University of Brest and any one of nine Moroccan universities. The first year of study takes place in Morocco, the second in France: 6 months of study at Brest, followed by a period of 6 months in France, with pre-employment in Morocco.

Both mobility schemes use internship as a placement mechanism. All stakeholders share a single goal: the recruitment of Masters graduates. French companies' expectations of Moroccan interns are high, especially since they are considered to be (and indeed are) normal French Masters graduating students. For almost all Moroccan students, this internship in France is their first encounter with the industrial world and its expectations. Some interns experience difficulty in adopting a professional attitude and in leaving their student clothes at home—literally or figuratively. We have the same problem on a 5-year curriculum in Computer Science, where there is just one, final internship: moving towards the job market is difficult for most students. Preparing students for the real world was one of the main reasons behind the introduction of the PBL experience for Moroccan students.

Statistical Data

While the initial Moroccan partners followed a common curriculum framework (called Masters in Offshoring), the first year of the Masters in Morocco can now be performed in four quite different specialties:

- Networking and Systems: Ibn Zohr (UIZ-Agadir), Hassan II Mohammedia (UH2M-Casablanca), Hassan 1er (UH1-Settat) and Abdelmalek Essaâdi (UAE-Tanger) universities;
- Information System Engineering: Cadi Ayyad (UCAM-Marrakech) university;
- Applied Informatics Offshoring: Mohammed V-Agdal (UM5A-Rabat) university.
  1. Students' origin: *Table 1 shows the number of double Masters students for whom the University of Brest was responsible between 2010 and 2013 (the current year).*
  2. *Employment*: The cumulated counts of both mobility patterns give the hiring rate at the end of the internship. Table 2 presents the percentage of interns kept on at their companies following the internship. The overall percentage is 103 interns employed over 143 internships, i.e. a hiring rate of 72 %. But it may be that student reluctance to move towards a professional attitude is an important barrier to employability, the issue that first led us to introduce the PBL approach.

Content of the Double Masters Degree

The knowledge base acquired by the end of the first year may vary from student to student, raising a problem of heterogeneity—and this was the second reason for deciding to try out the PBL approach reported in this paper.

Table 1 Masters' students count by university of origin

University	10–11	11–12	12–13	Σ
Agadir (Ibn Zohr)	5	5	1	11
Casablanca (Hassan II Mohammedia)	9	8	5	22
El Jadida (Chouaïb Doukkali)	–	3	2	5
Fès (Sidi Mohamed Ben Abdellah)	–	–	5	5
Kenitra (Ibn Tofaïl)	9	5	3	17
Marrakech (Cadi Ayyad)	2	4	4	10
Rabat (Mohammed V-Agdal)	6	6	5	17
Settat (Hassan 1er)	–	2	–	2
Tanger (Abdelmalek Essaâdi)	–	2	2	4
Total	31	35	27	93

Table 2 Employment count after internships

Company	08 Int.	08 Hire	09 Int.	09 Hire	10 Int.	10 Hire	11 Int.	11 Hire	12 Int.	12 Hire	Σ
AtoS	3	3	2	2	–	–	6	3	2	1	**69 %**
Capgémini	6	6	13	10	–	–	–	–	3	3	**86 %**
HP-CDG	2	2	–	–	–	–	–	–	–	–	**–**
Logica	3	3	12	6	20	19	41	30	30	15	**68 %**
Total	14	14	27	18	20	19	47	33	35	19	**72 nn**

From September to March in the second year of the Masters, all students attend eight technical courses: Database and Java Programming, Development Environments, Object-Oriented Design, Distributed Systems, Web Technologies, Software Engineering, Information Systems, and J2EE Development. They also attend courses in English and Communication in French, and a course providing a general introduction to offshore context. The 6-month internship takes place from April to September. The programme curriculum has been designed to train engineers in the development (design, production and maintenance) of software projects, rather than just focusing the curriculum (as other GSD courses or programmes do) on offshore-specific aspects. The programme objective is to acquire a foundation of skills and knowledge on the new technologies and industrialization tools used in large software development companies. It is assumed that the processes, methods, techniques and tools of offshore development vary from company to company and are taught and mastered during the training internship, which should also be a formative period.

Problem-Based Learning

Introduction

Boud [7] introduces his book on Problem-Based Learning with: "*PBL is a way of constructing and teaching courses using problems as the stimulus and focus for student activity. [...] It is a way of conceiving of the curriculum as being centred upon key problems in professional practice*."

We have experience of applying PBL to the entire final year of a Software Engineering Masters degree [8]. We decided to infuse PBL in three courses. The selected courses are: Database and Java Programming (48 h), Software Engineering (60 h), and Information Systems (60 h): a total of 168 h—one third of the technical courses as a whole. They are taught by three professors, including both authors of this paper.

PBL is performed through PBL sessions. The PBL approach raises several issues that can be illustrated using the production of a TV series as a metaphor; when someone decides to create a new series, she develops the show's elements—namely, concept, characters, crew, and cast.

The concept and characters yield the background of each PBL episode. The concept of the PBL series is the maintenance and the development of an information system (IS). The characters are the representation of the different jobs that are involved in maintaining and developing an IS.

The crew is a group of people in charge of producing the PBL series. Crew are distinguished from cast, the actors. The crew is divided into different sectors, each of which specializes in a specific aspect of production. Some crew positions will be highlighted in this paper. Crew members are academics.

The cast consists of the actors who appear in front of the camera or provide voices for characters in the film. Actors are students. They have to learn, and portray, their characters.

In the film industry, the main production phases are pre-production, principal photography, and post-production. Pre-production begins when a script is approved. Pre-production tasks include storyboarding, construction of sets, props, and costumes, casting, budgeting, acquiring resources, etc. Principal photography is the actual filming of the episode, where people gather at a television studio or on location to film the scenes of the episode. Once principal photography is complete, the producers co-ordinate post-production tasks.

In our PBL production, pre-production consists of all tasks required to prepare the PBL session, including script writing—a major task. Since the purpose of the sessions is not to record episodes for broadcasting, but to focus instead on the role play, we will call this phase Enacting. We do not have post-production tasks.

The Practicum

The concept runs through the series, and in our case, concerns the development of information systems through successive phases performed by specialized characters who must stay in role. Concept and characters are set up in a practicum: all together on the sets where the sessions are performed, the decors used in each session, and the accessories required for interpretation of the characters.

1. *Architecture:* A Management Information System, called SIGILI, has been developed to meet the needs of our Informatics Department. SIGILI was designed to manage schooling and was used by administrative staff and programme managers. SIGILI is composed of three sub-systems:
   - SIGILI1, a schooling management system;
   - SIGILI2g, an internships management system;
   - eCompas, a competencies management system.

   The whole system was developed between 2005 and 2007 with the second author acting as project manager (the job he used to perform at software companies for 13 years prior to joining our university); each sub-system was developed by a team of 5–6 full-time interns during their 7-month Masters internship (17 interns in all). The three sub-systems use a 3-tier architecture in which the user interface, functional process logic, computer data storage and data access are developed and maintained as independent modules, on separate platforms. SIGILI1, the first sub-system, was developed with open-source tools and uses Eclipse/Struts as a development framework, and Tomcat as an application server. SIGILI2g and eCompas both use JDeveloper and ADF Faces as an application development framework and the Oracle Application Server. Oracle is used as the DataBase Management System (DBMS) in all three cases.
2. *Legacy, complexity and heterogeneity:* A major challenge for IT students is dealing with the complexity and heterogeneity of legacy systems. Information systems are built through successive projects, with people, processes and technologies changing over time. A typical banking or insurance information system includes sub-systems and components produced over a period of 30 years. "*Problem-based learning can help students to learn with complexity, to see that there are no straightforward answers to problem scenarios, but that learning and life take place in contexts, contexts which affect the kinds of solutions that are available and possible* [9]." The SIGILI Management Information System and its technical environment will be used throughout all PBL sessions. The SIGILI data model is—like any IS—fairly complex: 90 tables, 60 views, 50 packages, 600 triggers, and 270 indexes. SIGILI code is managed within several configuration software components. The SIGILI infrastructure relies on different technologies. This complex, heterogeneous, legacy environment is the practicum in which PBL sessions run—a software studio corresponding to studio facilities that are used to make episodes of a series.
3. *SIGILI artefacts:* As mentioned in previous sections, a key component of the practicum is the SIGILI Information System. Although the work has been done by interns led by an experienced project manager, the project manager has never accepted weak deliverables—because the priority was not the project but rather the internship learning outcomes. Moreover, since the major objective of the internships was the learning-by-doing of software engineering processes, the development cycle was performed with a rigor that might not be matched in real software companies, resulting in an exhaustive set of major deliverables issued in a software project at our disposal. Obviously, the purpose of these project artefacts was not to serve the PBL approach—which we built only recently—and most of these need reworking before they can be used in a PBL setting. SIGILI artefacts are part of the furnishing required to run PBL sessions and form a set that is comparable to a film set (decor and props used in a film).

Pre-production Tasks

An important job in the pre-production crew is—in our opinion—that of the scenario writer. Savin-Baden and Howell Major [10] conclude a chapter on curricula models with "*In problem-based curricula the problem scenarios should serve as the central component of each module [. . .] the starting point should be a set of problem situations that will equip students to become independent inquirers [. . .] and perceive that there are also other valid ways of seeing things besides their own perspective*."

A PBL session should be run according a scenario that is intended to be interpreted on the basis of student performance, rather than serving as a "finished product". From our experience, a PBL session works well when a story is told and when students feel themselves involved in the story. "*Storytelling is one of the most powerful techniques we have as humans to communicate and motivate* [11]." Hence, the writing of PBL scenarios is an activity very close to screenwriting—and PBL session designers act as screenwriters and are responsible for researching the problem and its story, developing the narrative, writing the screenplay, and delivering it, in the required format, to the PBL tutors.

Screenwriting theories help writers approach screenplay by systematizing the structure (Goldman's famous quote "Screenplays are structure" [12]), goals and techniques of writing a script. In the three acts paradigm, act I is the setup (location and characters), act II is the confrontation (with an obstacle), and act III resolution (culminating in a climax and a dénouement). Field [13] preached the three-act structure at 1/4–/2–1/4 proportions, built around page-number-specific turning points. 1/4–1/4–1/2 proportions are more appropriate to the case of problem-based learning. In a 4-h session, 1 h will be devoted to understanding the setup, then students will spend 1 h getting to grips with the problem and tackling obstacles, and resolution will take more than 2 h.

1. *Problem design:* Curricular content must be organized around problem scenarios rather than subjects or disciplines. One key aspect for designers is that we just have to accept the amount of curriculum knowledge that will be taught and learnt, without allowing resentment about this to get in our way. The complexity of problem design is a challenge to many tutors implementing problem-based learning. Relying on previous experience, each author designs their own problems.
2. *Development cycle:* The plot of the PBL sessions concerns the maintenance or development of an information system. Practical understanding of the development cycle of an IS is an underlying objective of any PBL session. PBL sessions can be grouped in logical units, each related to a phase of the development cycle: maintenance, coding, design, etc. It will gradually be revealed to students that each PBL session is contributing to some extent to the development of a new sub-system. Our development approach relies on a waterfall process: requirement capture, requirement analysis, design, implementation. Like most information systems, we are using a systemic method. First, data and processing have to be separately modelled, and then coupled to constitute a unique and integrated system. The building of the system moves through different abstraction levels: statement of work, requirements, design and implementation.
3. *Artefacts:* software development activities rely on work products, called artefacts, either as inputs or as outputs. PBL scenarios are played out within software development phases where output artefacts of one phase are used as input artefacts for the next. Successive cases should rely on sound and complete artefacts (even though they should, ideally, have been produced by students). But it might happen that students have been unable to solve the problem and produce strong artefacts—so that their weak artefacts have to be replaced with strong products. Hence PBL designers have themselves to produce good artefacts to accompany the case; otherwise tutors will find themselves unable to run successive cases with students. To understand the burden of this task, recall that an episode (a PBL session) will go through successive scenes, each scene requiring a different film set, which includes the furnishings and all the other objects that will be seen in the scene. For each scene of the PBL session, a new artefacts set is required. Unfortunately, in most cases, the artefacts have to be built by the PBL designer, acting as head carpenter, set decorator and prop maker, to use film industry terminology.
4. *Inverting the cycle:* project-based approaches have to follow the development cycle along its normal path: from requirements to code. During a project, students are supposed to learn the different phases according to the waterfall schedule. Unfortunately, teaching and learning are much more difficult in the uphill phases than they are in the downhill phases. Nobody will try to learn to ski at the top of a mountain where the runs are vertical; instead we learn where the slope is gentle and gradually move up. Applied to software engineering, this means that students are passing through an inverted cycle; the first sequence of PBL sessions is intended to master the implementation activity (from design to code); then a steeper segment is envisaged: the design activity (from requirement analysis to technical solution design); and the last PBL sessions sequence is devoted to requirements analysis, the steepest part of the cycle.

Enacting the PBL Sessions

Bear in mind that courses chosen for PBL are centred on the development (in the broad sense of software engineering: from requirements to implementation) of information systems.

In a systemic development method, the first phases aim to reach sufficient consensus on problem understanding to produce, as a basis for the next phases, a conceptual data model (as an E-R schema or an UML class diagram) and a conceptual processing model (such as a use case diagram or function hierarchy). Based on this broad understanding, data and process modelling may, to some extent, be separately modelled. Later on in the cycle, data and processing implementation will be coupled again and tightly integrated. Since the PBL sessions are focused on the left branch of the V-model, we gather the PBL sessions into a three topic-breakdown: information system engineering (data & processing), database server (data), and application server (processing).

Apart from the development cycle dimension, systemic methods also consider a dimension using an abstract-concrete axis in which models transition from abstract representations to concrete constructs with three different levels: conceptual, logical and physical. Broadly speaking, the "information system engineering" topic focuses on conceptual and logical levels, while "database server" and "application server" topics focus on the physical level. As mentioned in the previous section, we have inverted the development cycle so that the first PBL period is related to physical models.

1. *Database server*: due to student diversity, very few prerequisites are required, mainly a knowledge of SQL DDL and DML. The first sessions are intended to improve student familiarity with real-scale database schemas. Examples of PBL sessions are:

- Restructuring a set of Data Definition Language (DDL) scripts in a design-based hierarchy
- Checking consistency between code artefacts and technical detailed specification
- Refactoring the DDL sources of a complete sub-system according to naming and organization rules

  Once a practical understanding of what a real-scale physical data model is, the next step is to train students in data implementation activities, i.e. transforming a logical model into DDL constructs. It should be pointed out that an understanding of this transformation is obviously key not only to successful implementation but also to successful design. Hence, our approach is to perform a retro-design of the DDL sources prior to the implementation itself. In the educational field, retro-engineering is an inductive approach. It is the reconstruction of a process from back to front, having the result of an activity as its starting point. Examples of PBL sessions are:
- Retro-designing a set of DDL sources (the physical model) in a logical model
- Producing (mostly generating) the DDL sources again from the logical model and drawing up the logical model and iterating the generation process until the logical model can serve as a reference for the development of the data server side of a complete sub-system.

2. *Application server*: once again, due to student diversity, very few pre-requisites are required, mainly a knowledge of Java. The first sessions are intended to familiarize students with the application development environment (JDeveloper/ADF Faces). Examples of PBL sessions are:
   - Running a step-by-step tutorial, then applying it to programming a small software component having a similar structure
   - Retro-designing then developing a set of Web pages with the user's manual yielded as specifications
   - Performing a code review on an existing module

   Obviously, with a complex development framework such as Eclipse/Struts or JDeveloper/ADF Faces, a long learning curve is inevitable, and such PBL sessions are only intended to prepare students to implement either interactive or batch processing functions from a design specification. Unfortunately, programming tools do not provide the same maturity as data modelling tools, and there is no substitute for programming experience. PBL sessions are similar to typical programming labs, except in that they take place in a real system and can be related to the database server PBL sessions. To assist students in using a complex development environment, some areas of PBL lessons are formulated as a tutorial, scaffolding students if necessary. Examples of PBL sessions are:
   - Integrating existing pieces of code in a bottom-up approach
   - Examining the gap between the solutions provided in a tutorial and expected implementation
   - Finally, developing—in a traditional fashion—the code of a sub-system component
3. *Information system engineering*: as mentioned before, database server programming and application server programming were performed in relatively-independent PBL sessions, and focused on the physical levels. We now reach the uphill phases: requirement analysis and software design—and deals with conceptual and logical models or logical models only. Both data and processing functions are modelled. At the time of writing, an initial PBL period of 8 weeks has been completed and reported on in this paper. During the upcoming period, PBL will be applied to analysis and design. We will continue to climb the mountain from bottom to top, learning software design before requirements analysis. The inductive approach will be used: from detailed design to architecture, from architecture to requirements. The last sequence of PBL sessions will be devoted—at last—to performing the uphill phases in the usual, top-down fashion—from requirements to architecture, from architecture to detailed design, from detailed design to implementation—with the practical knowledge and skills gained during the inductive PBL sessions.

Students' and Teachers' Role

Active learning refers to several education paradigms that focus the responsibility of learning, on learners. PBL is one active learning method that follows a constructivist perspective in learning. Constructivism can be summed up in two fundamental statements [14]: (1) learning is defined as an active process for knowledge building rather than a knowledge acquisition process; (2) teaching is essentially aimed at helping students in this process rather than transmitting knowledge.

Among practices belonging to the constructivist stream (and cognitive psychology), D. Dwyer [15] and J. Tardif [16] define a learning paradigm, in opposition to the main teaching paradigm.

1. *Teachers' roles:* J. Tardif defines teachers' roles as creators of pedagogical environments; interdependent, open-minded, critical professionals; development instigators; mediators between knowledge and students; coaches; collaborators for the student success of a whole school.

As mentioned in [17] "*In many universities, the adoption of problem-based learning is adding another dimension to* *what it means to be a lecturer in higher education*." Among the roles mentioned above, we emphasize the roles of creating pedagogical environments for the PBL sessions and of coaching whilst PBL sessions are running. Both authors feel they have a lot to learn themselves about the job of being PBL coaches (called PBL facilitators in the literature). We lack support from the university for those staff who are Problem-Based Learning facilitators. We also have little understanding of the complex interactions between team and facilitator during the PBL—and how both sides adapt their behaviour as PBL practice matures.

2. *Student roles:* J. Tardif defines student roles as investigators; co-operators sometimes experts; clarifying actors; strategic users of available resources. Among the roles mentioned above, the investigator and strategic user roles are most important.

PBL research is usually enthusiastic about PBL adequacy and effectiveness applied to engineering and medical science. For instance, [18] claimed that "*Student learning changed and student knowledge increased as a result of implementing PBL*." Satisfied students report the same viewpoint. But, as pointed out by Boud [7]: "*The principal idea behind problem-based learning is [...] that the starting point for learning should be a problem, a query or a puzzle that the learner wishes to solve*." But it can happen that some (or all) students do not wish (or are unable) to solve a problem. Another point is that students do notice when, for one reason or another (inadequate preparation, lack of experience of the PBL tutor, weaknesses in the inputs artefacts provided, etc.) a PBL session fails to work. Unless students sign up to the PBL approach, they might use the failed lessons to weaken the approach. Sweenev [19] clearly pointed out that the PBL concept should be clear to all and that everybody should understand PBL to mean the same thing, otherwise it may frequently induce discomfort, confusion, antipathy, lack of co-operation and general disbelief in PBL.

Assessment

If we consider the SWEBOK topics addressed in the PBL series (http://www.computer.org/portal/web/swebok), they belong to three Knowledge Areas (KA): software requirements, software design, software construction. Annex D of SWEBOK presents a classification of KA topics according to Bloom's taxonomy: Knowledge (K), Comprehension (C), Application (AP), Analysis (AN), Synthesis (S), Evaluation (E). We consider the scope of PBL sessions and mention the topics addressed within the sessions together with the associated Bloom level in brackets:

- SW requirements sessions are focused on requirements classification (AP), conceptual modelling (AN), architectural design and requirements allocation (AN), software requirements specification (AP)
- SW design sessions are focused on architectural structure and viewpoints (AP), structured design (AP), object-oriented design (AN)
- SW construction sessions are focused on construction design (AN), construction language (AP), coding (AN)

All topics are AP-classified (action verbs: apply, change, construct, manipulate, operate, produce, solve, use, ...) or AN-classified (analyse, compare, deconstruct, identify, illustrate, infer, outline, select, ...). Obviously, assessment cannot be performed in the same manner as usual. PBL assessment is part of the PBL itself, as is true of almost all active teaching approaches—what J. Tardif [16] calls "the entrenchment of assessment in learning".

Our assessment relies essentially on portfolio assessment. When a PBL session artefact is delivered, the tutor examines it and provides feedback about certain points to be improved upon or started over. Ideally, feedback is given in front of the authors, allowing the authors to delve deeper, discuss, and even contest remarks made by the tutor. But the workload may be too heavy and we also practice a stop-and-go approach: it works or it does not work. In the latter case, students are poorly assessed but are provided with a working artefact that allows them to continue their work.

Formal examinations take place every 2 months; this was therefore the case at the end of the fully-PBL period. Examinations are based on work performed by students during the session, and may be considered as PBL sessions themselves—though without any help from tutors.

Perspectives and Conclusion

This article presented the introduction of a PBL approach in a mobility programme for Moroccan students coming to France, governed by a strong principle of directing skills for the benefit of Moroccan economic development. However, student heterogeneity and lack of industrial experience confronted us with new challenges, hence the PBL approach was trialled on a few courses in order to develop a reflective practice.

Although PBL has proved its worth in engineering education, an immediate conclusion is that the price of starting a PBL approach is high, a drawback to bear in mind. Our experience is too limited to draw any conclusions about student perception of PBL or the pros and cons of the approach. We plan to relate student participation in PBL with their involvement in problem-solving during the internship—one of the fifth assessment indicators used in awarding a mark to the internship.

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Composition of Learning Routes Using Automatic Planning and Web Semantics

Ingrid-Durley Torres and Jaime Alberto Guzmán-Luna

Abstract

This article describe how to combine automatic planning techniques and web semantics technology to organize, design and customize (personalize) by composing learning route objects for e-learning. The purpose of automatic planning is an unanticipated creation of a sequence plan subordinated to learning objects (i.e. learning route) which is attained from other pre-existing objects (i.e. composition); on the other hand, the paradigm of web semantics is used to deal with the significant heterogeneity expressed among a diversity of mental models of faculty members, students and authors of their own learning objects.

Keywords

Automatic planning • Web semantics • E-learning

Introduction

In an e-learning environment, students who share actions with faculty members (professors) and authors are the key protagonists [1, 2]. Authors (who may also be faculty members) create learning objects (LO), which are generally kept under the control of a repository [3]. Those LOs are used by professors to build courses aimed at satisfying the need to teach a given domain of specific knowledge [4]. Regarding students, they have greater autonomy and responsibility in their learning processes, for they access the course on the web, overcoming obstacles as time and space. Nonetheless, *e-learning* does not only deal with a special given type of learning [2]. Students are quite diverse when it comes to pre-knowledge, skills, aims, learning rates and ways of learning. Thus, the student target group is quite heterogeneous. To satisfy the needs of each one of them, a set of requirements and actions must be fulfilled [5], aiming amongst others, customizing and adapting the course [2].

An emerging solution which is successfully applied in other domains corresponds to a composition process which is attained on one of its most promising lines by implementing planning techniques and the automatic interaction of pre-existing elements to generate new elements that suit to a user's specific needs when those needs cannot be satisfied by the preexisting elements.

Composition transferred from an e-learning setting may be used to build learning routes; these understood as sequential subordinate unanticipated LO interconnections which satisfy a user's specific knowledge objective [5]. Applying composition customizing methods based on planning may utilized successfully to surpass the various difficulties of customization and contextualization of current learning platforms; generating learning routes as a solution to a user's requirement is an innovative task, and there are important outstanding works in that field [5–7]. Nevertheless, they detour from the

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_43,

topic of semantic heterogeneity related to each protagonist's mental representation (author, student or faculty member).

Due to the autonomy of an *e-learning* environment, every LO is framed and commonly used by authors or professors (respectively), associating their own specification of syntax and even their own meanings (semantics). Furthermore, bearing in mind that there are several authors, it may be possible that some or none of them could coincide many times with the specifications coined by the professors and students themselves who at the end will be the users of those LOs. This aspect, tends to be more complex when it deals with the building of systems which can achieve automatic synthesis, for some LOs may aim, for instance, the same learning objective even though the specification may be syntactically diverse (Ex. Teaching what a "car" is, is the same as teaching what an "automobile" is), or may have the same syntactic specification associated in its objective, but has a different meaning (Teaching what a "star"—celestial body—is, is not the same as teaching what a "star"—famous person—is). To obtain customized learning routes which fulfill the objectives a student has formulated, but which at the same time reflect a consensus in the mental representations of authors, professors and students, this article describes a form of solution applying jointly automatic planning techniques and we semantics technologies.

To provide a more detailed vision in this paper, the article is organized as follows: Section "Frame of Reference" defines the main concepts related to this proposal's framework. Section "Ontological Formalization" describes the ontology developed. Section "Mechanism of Learning Route Composition", presents all the details of the mechanism of learning route composition with a brief description of the functionality of each one of the component modules. Section "Experimental Case" is an experimental case with its respective test results. Finally, Section "Conclusions and Future Work" compiles conclusions and future work arising from the development proposed herein.

Frame of Reference

Description of the LOs

Formally, there is not just one definition of the concept of an LO [4, 8]. Nonetheless, it is convenient to consider it as an attempt to unify; the following definition. An LO will be understood as all the material structured in a significant way, and it must be related to a learning objective which must correspond to a digital resource that can be distributed and consulted online. An LO must also have a registration form or metadata that includes a list of attributes which not only describes the possible attributes of an LO, but also allows to catalogue and exchange it". In this setting, standardization is a notably recurrent topic since when one handles various types of resources for different applications and with different technologies, it becomes a key topic to continue operating current applications and even to make them grow.

Among these initiatives it is worth highlighting: an LOM [2]; this standard specifies the syntax of a minimum set of metadata required to complete and to adequately identify, administrate, locate and evaluate an LO. Its purpose is to facilitate the task of searching, sharing and exchanging LOs for authors, students and automatic systems.

Web Semantics

Formal models that support web semantics [9], provide more knowledge for contents (images, videos, links), enabling the automation of many tasks currently performed by humans. In particular, semantics seeks to produce a world where ontologies [10] allow greater task automation by structuring resources available on the web, so that software agents may analyze and execute processes such as searching, retrieving, invocation, interoperability, and automatic execution [11]. To fulfill these tasks, said ontologies must be sufficiently expressive and must be able to describe the properties of related Domains.

Historically, Web semantics was introduced with an RDF [12] (Resource Description Framework) which allows the representation of classes, properties, sub-classes and more class hierarchies. That RDF has evolved into a more expressive language called OWL [13]. OWL (1.0) enabled the following properties: (1) Class definition by means of restrictions on property, values or cardinality. (2) Class definition by means of Boolean operations on other classes as intersection, union and complement. (3) Relations among classes (For ex. inclusion, disjunction, and equivalence). (4) Properties of relations (as inverse, symmetric, transitive). (5) Cardinality (i.e. "just one"). (6) Equality and inequality of classes, (7) enumerated classes. (8) cardinality restrictions (9) asymmetrical properties, reflexive and disjunctive, among others.

Composition of Learning Routes

In essence, in the compositions of learning routes, it is the LO themselves which interact among themselves to form a road perfectly adapted to the learning needs a student has formulated. Then, the purpose of composition of learning routes consists on the dynamic creation (unanticipated) of an LO sequence obtained from other pre-existing LO. This route is one which must follow in strict order a student to reach learning objectives.

In general, a learning route composition problem for the scope of this proposal may be defined from two approaches.

The first corresponds to the modeling of a course commonly related to a professor's vision. The second, on the other hand, involves the representation of the need to learn, formulated by a student. Under these two considerations, two formal definitions are generated inspired on the LRNPlanner [14] for the composition of learning routes, which are stated as follows in their corresponding order.

Definition 1. A learning route composition problem from a course modeling perspective includes two views, a conceptual view which defines the general lines of the course structure. It is a conceptual map expressed according to an abstract ontology of concepts directly related to another domain ontology with which one represents the formative intentions and/or competences that will be acquired in a course and their relations, accompanied by precedence relations '*IsBasedFor*' and '*IsRequiresBy*' (and their inverse), which indicate cause-effect relations among objects, and they correspond with LOM terminology. A view of tasks which applies a decomposition of concepts in tasks; that is, LO themselves. It is a matter of indicating how each of the concepts will be learned.

Definition 2. More formally, a learning route composition problem from the representation of the modeling of a need to learn may be described as a tuple (S,So,G,A,R), in which S is the set of all possible states of knowledge. $So \ \varepsilon \ S$ denotes a user's initial state of knowledge (student), $G \ \varepsilon \ S$ denotes the objective state of a user's knowledge, expressed by a set of concepts related to a formative intentionality in which the composition system will try to search. A is the set of actions which represent the LO, the composer must consider to change from a state of a user's knowledge to another state of knowledge, and the translation relation $R \ \varepsilon \ S \ x \ A \ x \ S$ defines the precondition and effects to perform each action (LO). Both definitions are compatible and they are carried out in a strictly sequential order; in other words, it is necessary to mold a course first as an LO dynamic composition, and later transfer it to planning problem related to a student's specific profile.

Ontological Formalization

Learning Ontology Domain

Since one of the current priorities lies in the reusing of the teaching content; an LO will always be used as a device to acquire the same knowledge. This is perhaps the main reason why when an LO is born, its creators provide it with the greatest freedom of use and the association of the formative intentionality becomes the responsibility of the person who implements it in a learning setting.

Under these guidelines, the semantic formalization of this element is directly associated with an instance of the *concept* class, of the LOD (*Learning Ontology Domain*) ontology. With the development of LOD, it is necessary to demonstrate how it is possible to manage LOs with a unique information model and this way face the semantic heterogeneity associated to the diversity of meanings present among various participants (LO creators, teachers and students) involved in a learning process. This way it is possible to define a non-ambiguous shared vocabulary that involves various mental representations that a participant has for each concept superimposed on contrasting syntactic specifications.

In this sense, this ontology has been instantiated under such concepts, and at the same time, it is an important part of the description of course contents and the formulation of the requirement of the learning objectives a user wishes to fulfill [13]. For this specific case, an LOD has been inspired on the SKOS-Core Model [14] (see Fig. 1).

LOs instanced with the concept of˙ "offspring" generating the possibility of duplicating or not précising correctly neither the objectives to be taught nor the objectives which are to be reached. This is the main reason why it was decided to retake only the definitions of concept (*skos:Concept*), which is defined as a unit of thought that can be described. Likewise, the idea that each concept may only have a preferred label has been retaken, which is what documentalists call descriptor or preferential term and a limited number of alternative labels called non-descriptor or non-preferential. The coding of the labels corresponds to preferential and non-preferential terms belonging to a concept which is carried out by means of *skos:prefLabel*

assimov_laws	
skos:semanticRelation =	issac_asimov
	legislation
skos:broader =	legislation
skos:altLabel =	Leyes de Assimov
	assimov laws
skos:broaderTransitive =	legislation
skos:related =	isaac_asimov
…	

Fig. 1 Definition LOD, in the domain of classification

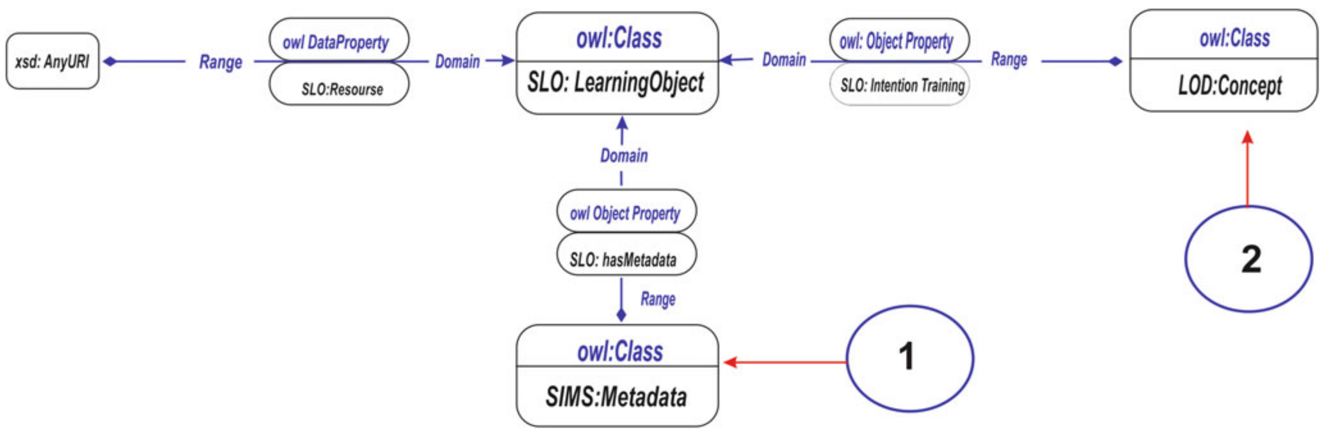

Fig. 2 Definition of ontology SVC

and *skos:altLabel* properties respectively. This second label represents the relation of synonymy or equivalence between two concepts. Moreover, you contemplate the *skos:Hidden,* which allows the generation of the same *skos:prefLabel*, but this time considering some orthographical errors or even typos. Inclusively, specification of *skos:-languageconcept* was contemplated to specify the same concept in other languages. On the other hand, relations defined by *kos:SemanticRelation* have been completely ignored.

Course Modeling

However, retaking the idea of dealing with the semantic heterogeneity among students, professors and authors, the route composition model goes beyond simple ontological domain modeling, and it includes semantic formalization of what a learning route must be in accordance with Definition 1, mentioned above. This is why; the conceptual view is also represented ontologically and named SVC (*Semantic View Concept*). It only contains concepts defines in this case as concept instances (*Concepts*) of an LOD (*Learning Ontology Domain*), as shown in Fig. 2. It is important to highlight that with SVC, a concept is represented abstractly while with LOD the concept is instantiated into a concrete value of a specific domain.

LOD, defines a concept like *LOD:Concept* which belongs to an *OWL:Class*. Thus, it is possible to build a network of concepts with SVC depending on the cause-effect relation which may take place among the various formative intentionalities. To do so including specifications as *owl:ObjectProperty-SVC:isrequire* and *owl:ObjectProperty*:- *SVC:isBasisFor*. With this specificity, it is possible to show when an LO must be seen before another, or when, only a few of them must be seen before seeing another.

Mechanism of Learning Route Composition

From Course Modeling

Basically, this sort of composition cares for modeling courses (in other words what will be taught and how will it be done); the main idea in this stage consists in creating a new structure as a sequence flow, in which some LOs are prerequisites of others. This LO sequence represents the route of the course. From a general perspective, the design of learning shares the following characteristics: (1) a course is initially built by asset of LOD concepts. At the same time, these concepts may be reached by means of one or more activities. For example for a "Robotics" course, the first unit represented by the concept of "Introduction to Robotics", may be achieved starting from an introductory reading which may be reached by various LOs (reading a text from a part of a book and the showing of a video). (2) Each activity may be more or less appropriate for a student depending on the student's profile. To define such convenience, a set of theories which classify a student in one or another profile are used [15, 16]. This set of learning styles is then translated as rules depending on the planning paradigm. (3) Activities and concepts may be precedents or relations among them; for example, before reading about "Autonomous Robots", a student must have some knowledge on the concept of "Types of Robots". These precedents or relations support themselves on four types of specific relations: '*IsBasedfor*' and '*IsRequiresby*' (and their inverse *IsBasedOn* and *Requires*), as it is shown on LOM terminology.

These relations are interpreted as a must; in other words, they must be complemented prior to starting another concept (Or activity). For instance, suppose that "B *IsRequiereby* A" and "C *IsRequiere* B". In this case, B and C must be terminated before doing A. In the case of *IsBasedfor* elements, at least one of them must be completed before starting another. Supposing that "B *IsBasedfor* A" and "C *IsBasedfor* A", just one B or C must be completed prior to starting "A". Moreover, professors may recommend some concepts starting from the use of another relation also referenced in the LOM named, *References*, that even though it does not mean a mandatory, it may be treated as a recommendation that may be approached.

- Every learning activity belongs to a type of resource of an LO (in LOM: *LearningResourceType*); Furthermore, it may have a positive or negative impact on the result of the activity. Hence, it is associated to the student's profile. For instance, a class is very recommendable for verbal students according to Felder [15], but not for visual students.

The idea, then, is to create two abstract layers that guide a professor in the building of a course (defined by means of the installation of the SVC). The first layer of concepts describes the general content of the course its formative intention indicated as that which the professor wants to teach and the order in which the professor wants to do it. The second stage describes the possible forms and tasks which may be used to reach this concept.

Assignment view: it inherits information from a concepts view and associates assignments to each of the concepts defined in the first view. This view only includes assignments, and it corresponds to a wider detail of the first view, where each concept is transferred to one or several assignments which must be carried out to fulfill it (the concept). This view is built similar to the concepts view, receiving the same relations or recommendations as the concepts view. From the most simple point of view an assignment is only associated to one sole concept, but faculty members or professors may create a network of assignments as detailed as they wish assignments, and it corresponds to a wider detail of the first view, where each concept is transferred to one or several assignments which must be carried out to fulfill it (the concept). This view is built similar to the concepts view, receiving the same relations or recommendations as the concepts view. From the most simple point of view an assignment is only associated to one sole concept, but faculty members or professors may create a network of assignments as detailed as they wish.

The converging of the both views forms a precedence network of LOD concepts that indicate what is to be taught as activities that must be carried out defined in this case as a learning route corresponding to a course modeling.

From a User's Learning Requirement

The composition of a learning route from the point of view of a user's learning requirement is directly related to the formal specification of a planning problem, which includes collections of actions with pre-requisites ands results (preconditions and effects respectively). Inspired in [16]. When an action supports another this generates a causal link between them, meaning that the preceding action is finished before starting a succeeding action. With these actions, it is possible to establish a plan of the actions which will be transferred to users (students) from an initial state of knowledge of a course to a state in which formulated objectives are achieved by users (students) themselves. Expressed analogically, with a virtual learning environment, users (students) express their learning requirement depending on one or various concepts of domain specific knowledge, these concepts are part of a course's contents (SVC + LOD), and they lead to one or more associated activities. This requirement must be achieved from a state of a student's initial knowledge of that domain (which is even considered null, for the specific case in which an individual knows nothing of a domain); also, including at the same time considerations regarding learning preference and style. Thus, the learning route for this case constitutes a (plan) sequence of learning activities associated to knowledge domain, and customized for a student that the student must follow to fulfill that student's objectives. In this case, the building of a planning problem is done by means of an interpretation that can be conducted computationally on both types of defined relations which may be interpreted by a planning mechanism as AND relations and OR relations; they refer to *RequiresBy* and *IsBasedFor* respectively. Thus, all the concepts defined as AND, must be totally completed before seeing the next, while at least one of the OR relations must have been completed to see what is next.

As an attempt to transfer both specifications, in one sole model (Planning Domain Definition Language PDDL), *Definicińn.3* was born, which was expressed by the (S,So, G,A,R) tuple, where S is a set of all the possible states of knowledge defined by the course; $So \ \varepsilon \ S$ denotes a (student) user's initial state of knowledge within the state of the course, $G \ \varepsilon \ S$ denotes the state of the objective also of a (student) user's knowledge within the state of the course, expressed by a set of concepts associated to the formative intentionality, in which the composition system will try to search (SVC + LOD). A is a set of actions which represent the LOs which the composer must consider to change from a user-student's state of knowledge, to another state of knowledge, and the translation relation $R \ \varepsilon \ S \ x \ A \ x \ S$ defines the precondition and effects to execute each action (LO) (See Table 1).

As it is deduced from the tuple, states S are defined depending on the course model; this is why, this stage can only be achieved once that, at least one of the learning routes of the course modeling has been defined and it only works on one course at a time; then, there is an attempt to define: (1) Which assignments best adapt to a given student's profiles,

Table 1 LOM to PDDL transformation

OWL (SLO, SIMS, LOD)	*Domain PDDL*
LOM:General: LOM: Identifier *LOM*: Title *LOM*: Language *LOM*: Description	***:action name_OP*** :precondition (*language-level languageOA ?who*)
***LOM*:Technical**: LOM:Format LOM: Size LOM: Location LOM:Requirement LOM: Duration	: precondition (*format ?who formatOA*) (*size ?who sizeOA*) (location *?who LocationOA*) (requirement *?who multimedianOA*) (duration ?who durationOA)
LOM Educational: LOM: Interactive Type [Felder, 1996] LOM: Learning Resource Type LOM: Difficulty	: precondition (learning style ?who styleOA) (user_favoriteformat ?who ResourceOA) (user_difficulty ?who diffcultyOA) : effect (task_OA_OP done ?who)
OWL:Class LOD:Concept	:precondition (user_knows ?who ConceptLOD) :effect (user_knows ?who Concept)

and which are the resources required to achieve an objective of knowledge expressed by a student depending on the concepts of the course (SVC) already instantiated in a domain of specific knowledge (LOD)? (2) Which LOs must follow a student? To do so, the set of LOM mega data associated to each LO is translated to a planning domain as an action, where preconditions will be defined as two types (1) some of knowledge directly associated to LOD concepts and to the assignments; (2) some of precedence associated to OWLs: *ObjectProperty* of SVC represented by *SVC:isrequire* and *SVC:isBasisFor*. The effects themselves correspond to the statement that says that the LOD concept is already known and that LO's specific activity has already been carried out. (3) The convenience of the LOs in accordance with a student's profile is achieved by building a function called *fluent* (datum fluctuating within a planning process called "*reward*"), which will be in charge of incrementing a determined value of 1 if the learning LO is convenient for that student's profile or = in the opposite case.

Experimental Case

Mentioning the proposal of [14], a graphic tool was built to allow a professor to model a course depending on the relations of LOD ontology concepts, and was built in the domain of robotics (as it is shown in Fig. 3).

Aiming to generate planning domains starting from ontologies, a module able to transfer OWL specifications into a planning problem was designed and implemented, specified in a PDDL language. The translating component is a structure that models the specification of a planning problem, which is made up of two important files, *Domain* and *Problem,* starting from the use of a set rules. *Domai*n represents the planning domain, thought up to express the basic elements of domain theory; in other words, existing types (*type*), constants (*Constant*) and predicates (*Predicate*), as well as the actions (*EryxOperator)* which define it. The latter are constituted by preconditions (*PDDLPrecondition*) and effects (*PDDLEffects*) which describe action applicability. *Problem* represents the planning problem, which describes the initial state (*Init*) and the state of the objective (*Goal*) and the components which compose it. Once both files have been built, they are sent transparently to the planner so that it may instantiate and generate the user's most adequate learning route.

As a final goal, the degree of completeness of the learning routes finally built in this proposal. To evaluate this metrics three users experts in robotics were interviewed in such a way that they stated the number of concepts they knew of a total of concepts described on the route modeled as a course. Figure 4 shows a comparison of the total concepts recorded on the learning route compared to a curve of the concepts users recognized. The area below the

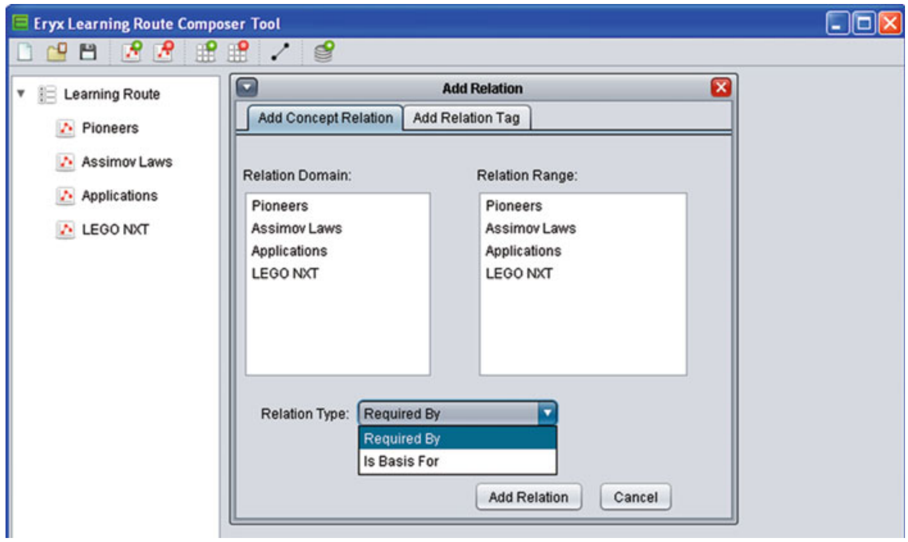

Fig. 3 Course modeling

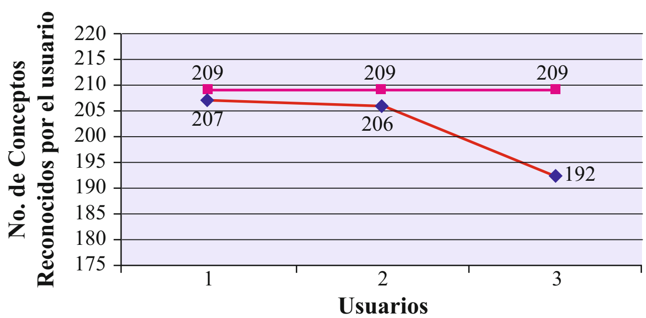

Fig. 4 Course modeling

curve of the series "Ontology Concepts" equals 627 = μ2, where, μ = Number of concepts recorded in the ontology. The area below the curve of the series "Known Concepts" equals 605 = α2, where, α = Number of concepts the users knew. The analysis of the results obtained, indicates, that the completeness of the route may be determined as 96.5 % (α2*/μ2).

Conclusions and Future Work

This article provides a brief analysis of the characterization process of a learning route composition problem under the application of an automatic planning technique, comprehensively bearing in mind the semantic heterogeneity of LOs. To approach this said characterization, the definition of an LO is considered again initially. Immediately after, the description of a semantic model is presented, represented by two OWL ontologies, which allow the specification of a specific domain (robotics) and an abstract representation of the course modeling. Both have the sole purpose of dealing with semantic heterogeneity and facilitating the task of automatic planning. Precisely, to achieve this last task, a translation schema was defined to allow converting a learning problem of a virtual semantic environment expressed in OWL into a planning problem.

Acknowledgment This work is funded by the Project 205010011129 "Web Intelligent Systems Group—SINTELWEB. Support for strengthening research groups or artistic creation 2012". Sponsored by Universidad Nacional de Colombia, Medellín.

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A Novel Dual-Error Approach to System Identification

H. Greeff

Abstract

Single error system identification techniques are widely used to estimate the parameters of dynamic mathematical models that are needed in a range of industrial applications. A novel Dual-Error system identification technique is proposed. It is based on a modification of the traditional single-error methods and shown to offer better accuracy for the estimation of model parameters. The benefits of the proposed method are demonstrated by a comparison with traditional methods when applied to both a simulated system and a DC motor.

Keywords

System identification • Dynamic system identification • Parameter estimation • Generalised error • single error • Dual-error

Introduction

In the identification problem, the aim is to model the actual system by determining its parameters in order to minimize the chosen norm of the modelling error [1]. This is done in order to best describe the dynamics of the system, in particular for applications in signal processing, communications and control [2, 3]. In general there are some common configurations described by well-known traditional parametric system identification methods, namely, Equation Error (EE), Output Error (OE) and Input Error (IE) [4, 5]. All three of these methods attempt to identify the unknown parameters describing the system model by optimizing a single cost function that is derived from the chosen error variable.

Recursive least squares (RLS) will be used for optimization of the cost function because it is able to describe the system as accurately as possible in real-time. This allows for improved adaptive control that is widely applied due the lack of robust online system identification methods [6].

This paper proposes a novel Dual Error identification method based on the commonly encountered OE and IE methods for system identification that operate on noisy input and/or output data. The proposed method is expected to outperform its traditional single-error counterparts for reasons that will be described in the paper. The current work is restricted to the open loop configuration for LTI systems and its efficacy will be demonstrated in both simulation and application.

Briefly, this paper is organized as follows. Section “Algorithm Development” describes the traditional single-error system identification methods. Section “Input Error Design” describes the design of the Input Error method while section “Comparison by Cost Criterion” draws a critical comparison between the respective methods based on the cost criterion. Section “Dual Error Method” describes the proposed Dual Error method. Section “Numerical Example” provides an illustrative example to show the effectiveness of the identification method proposed that is confirmed by its application to a motor system in section “Practical Implementation”. Finally, some concluding remarks follow in section “Conclusions”.

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_44,

Algorithm Development

It is assumed that the dynamics of the plant under investigation can adequately be defined around an operating point by a discrete-time transfer function model of the form:

$$G(z) = \frac{B(z)}{A(z)} \quad (1)$$

where

$$A(z) = a_0 + a_1 z^{-1} + \ldots + a_{n_a} z^{-n_a}$$

$$B(z) = b_1 z^{-1} + \ldots + b_{n_b} z^{-n_b}$$

with $a_0 = 1$. It is assumed that the orders of the numerator and denominators are known. The observed system input and output are

$$u(k) = u_0(k) + \tilde{u}(k)$$

$$y(k) = y_0(k) + \tilde{y}(k), \qquad k = 0, 1, \ldots N - 1$$

where u_0 and y_0 denote the noise-free input and output, respectively, while $\tilde{u}$ and $\tilde{y}$ represent measurement noise on the input and output. Both are independent of the input. Further, it is assumed that $\tilde{u}$ and $\tilde{y}$ are uncorrelated white processes with variances σ_u^2 and σ_y^2, respectively.

Given N samples of u and y, the function of system identification is to find the model parameters a_l and b_l, $l = 0,1,\ldots,n_a(n_b)$ such that the estimated model can be described by:

$$G_m(z) = \frac{y_m}{u} = \frac{\hat{B}}{\hat{o}} \qquad \text{for OE} \quad (2.a)$$

and by:

$$G_m(z) = \frac{y}{u_m} = \frac{\hat{B}}{\hat{o}} \qquad \text{for IE} \quad (2.b)$$

where $\hat{B}$ and $\hat{A}$ represent the numerator and denominator polynomials of the estimated model. The predicted input and output of this model are u_m and y_m.

The respective error signals that are needed for the cost functions can be computed as follows, for the EE, OE and IE formulations respectively

$$\begin{aligned} e_{EE} &= \hat{A}\, y - \hat{B} \\ &= y(t) + ay(t-1) - bu(t-1) \end{aligned} \quad (3.a)$$

$$\begin{aligned} e_{OE} &= y - y_m = y - \frac{\hat{B}}{\hat{A}} u \\ &= y(t) + ay_m(t-1) - bu(t-1) \end{aligned} \quad (3.b)$$

$$\begin{aligned} e_{IE} &= u \cdot H - u_m \cdot H = u \cdot H - \left[\frac{\hat{B}}{\hat{A}}\right]^{-1} \cdot H \cdot y \\ &= v(t) + \alpha w(t-1) - \frac{\beta}{b} y(t) - \frac{\beta}{b} ay(t-1) \end{aligned} \quad (3.c)$$

where

$$v(t) = -\alpha v(t-1) + \beta u(t-1)$$

$$w(t) = -\alpha w(t-1) + \frac{\beta}{b} y(t) + \frac{\beta}{b} ay(t-1)$$

are the modified measured input signal and predicted input signal, respectively as indicated in Fig. 2.

Further, H is a stable, minimum phase transfer function to ensure that the transfer function $G_m^{-1}(z) \cdot H(z)$ will have a proper and stable inverse. This is guaranteed on the assumption that the reference model structure has degrees corresponding to that of the true system (plant) G_0 and that the reference model G_m is stable and minimum phase.

The vector of predicted parameters $\hat{\theta}$ is obtained by minimizing the appropriate quadratic criterion based on the errors in Eq. (3). The corresponding LS cost function is then

$$J\left(\hat{\theta}_k\right) = \frac{1}{N} \sum_{k=1}^{N} e\left(k, \hat{\theta}_k\right)^2 \quad (4)$$

However, if $N \to \infty$ and for the condition of ergodicity then

$$J = E\left\{e^2(k, \theta)\right\} \quad (5)$$

It needs to be noted that the minimum of $\boldsymbol{E}\left\{J\left(\hat{\theta}\right)\right\}$ will not correspond to the desired $\{a_l\}$ and $\{b_l\}$ in the presence of input and/or output noise.

Input Error Design

In most cases the inverse of the predicted model G_m will not be causal and therefore not be allowed [4]. This problem can be overcome by including an additional function H(z) to ensure causality.

Specifically the inverse of the predicted model G_m is multiplied by H which is of the form

$$H(z) = \frac{\beta(z)}{\alpha(z)} \quad (6)$$

where

$$\alpha(z) = \alpha_0 + \alpha_1 q^{-1} + \ldots + \alpha_{n_a} q^{-n_a}$$

$$\beta(q) = \beta_1 q^{-1} + \ldots + \beta_{n_b} q^{-n_b}$$

with $\alpha_0 = 1$.

It is assumed that the orders of the numerator and denominators are known and equal to that of the true system G_0. The resulting combined system $G_m^{-1}(z) \cdot H(z)$ will then be causal.

Choice of Polynomial $\alpha(z)$ in H(z)

The denominator parameters of H(z) are used to determine the poles of its transfer function and these in turn determine the rate of convergence of the system. The position of the pole of function H can then be represented by

$$\alpha_l = -a_l^{speed} \tag{7}$$

To reduce the rate of convergence of the function H with respect to the true system G_0 the poles α_l tend to the unit circle in the z-plane. Setting the rate of convergence equal to that of the true system G_0 is undesirable since pole-zero cancelation could cause a masking effect in the system. It is therefore suggested that the rate of convergence of H be made significantly faster than the true system G_0 to ensure that the predicted parameters are not influenced by the addition of H.

Choice of Polynomial $\beta(z)$ in H(z)

The effect of H on the system should be limited to ensuring that the prediction model $G_m^{-1}(z) \cdot H(z)$ remains causal. In addition, it is desired that the DC gain of H be unity. These constraints are used to set β in Eq. (6).

Comparison by Cost Criterion

Generally, comparison of the respective methods include commenting on and evaluating the overall prediction accuracy of the methods [4, 5, 7]. However, in this section we will group the parameters by numerator and denominator, and then comment on the accuracy of predicted parameters in these respective groupings.

In particular, this can be done by investigating the relationship between the parameters and the cost criterion for each single-error method. To distinguish between the parameters in the cost criterion, the gradient can be evaluated in terms of the individual parameters. The gradient of the cost function $J(\hat{\theta}_k) = J(, \hat{a}, \hat{b})$ is the vector function

$$\nabla J = grad\ J = < \frac{\partial J}{\partial a}(a,b), \frac{\partial J}{\partial b}(a,b) > \tag{8}$$

For example in the case of a first order system, J is a function of two variables and thus the gradient is a two-dimensional vector. The grad function can be represented geometrically by a corresponding Quiver plot to ease analysis since this is a 2D representation of the gradient vectors at a set interval of points for the variables. Combining the quiver plot with a contour plot is useful since the gradients also illustrate the regions in which the function is increasing or decreasing.

The gradient of the cost criterion of the identification methods in section "Algorithm Development" can then be described by

$$\nabla e^2 = grad\ J = < e\frac{\partial e}{\partial a}(a,b), e\frac{\partial e}{\partial b}(a,b) > \tag{9}$$

Indicating the respective two-dimensional gradient vectors.

For the EE Method

The respective two-dimensional vector are defined by

$$\mathrm{e}\frac{\partial e}{\partial a}(a,b) = [e_{EE}]y(t-1) \tag{10.a}$$

$$\mathrm{e}\frac{\partial e}{\partial b}(a,b) = [e_{EE}][-u(t-1)] \tag{10.b}$$

where y and u are the output and input signals to the system, respectively.

For the OE Method

Similarly the gradient of the cost criterion of the OE identification method can then be defined. However, the respective gradient vectors vary and are described by

$$\mathrm{e}\frac{\partial e}{\partial a}(a,b) = [e_{OE}]y_m(t-1) \tag{11.a}$$

$$\mathrm{e}\frac{\partial e}{\partial b}(a,b) = [e_{OE}][-u(t-1)] \tag{11.b}$$

Then the output y_m of the proposed model G_m is given in terms of the parameters

$$y_m(t) = [-y_m(t-1)u(t-1)]\begin{bmatrix} \mathrm{a} \\ \mathrm{b} \end{bmatrix} \tag{12}$$

The relationship of the gradient vectors of the cost criterion with respect to the parameters can be represented graphically by the gradient of the cost criterion with respect to the respective parameter as shown in Fig. 1.

The vector field shows two invariant lines where the vectors curve. One runs at a slight angle from the left to the right, the other from bottom to the top. It can be observed

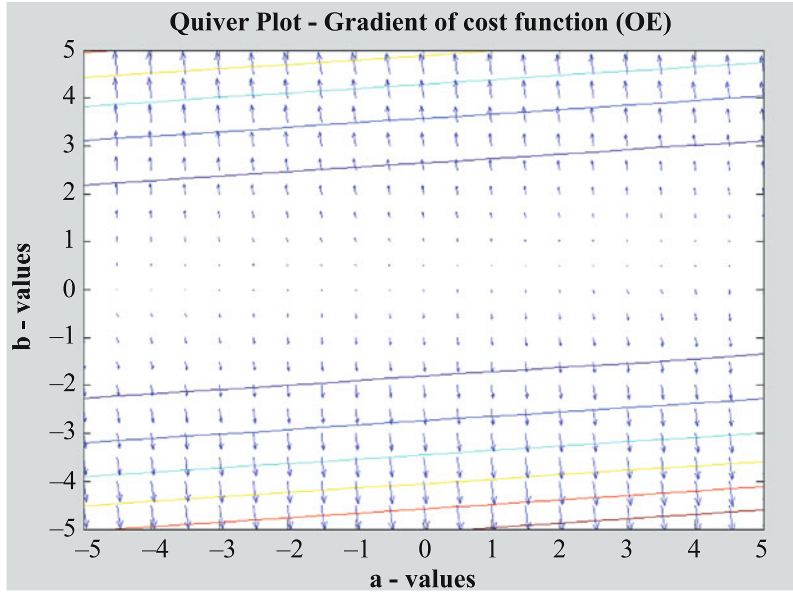

Fig. 1 Quiver plot of gradient cost function (OE)

that for some value of the numerator parameter b the gradient vector is minimized irrespective of the denominator parameter a. This confirms the linear relationship of the gradient vector described in terms of the numerator parameter *b*.

For the IE Method

The gradient of the cost function can also be described for the IE method. However, the respective gradient vectors vary and are described by

$$\mathrm{e}\frac{\partial e}{\partial a}(a,b) = [e_{IE}]\left(-\frac{\beta}{b}y(t-1)\right) \tag{13.a}$$

$$\mathrm{e}\frac{\partial e}{\partial b}(a,b) = [e_{IE}]\left(-\frac{\beta}{b^2}y(t) + \frac{\beta}{b^2}ay(t-1)\right) \tag{13.b}$$

where

$$v(t) = -\alpha v(t-1) + \beta u(t-1)$$

$$w(t) = -\alpha w(t-1) + \frac{\beta}{b}y(t) + \frac{\beta}{b}ay(t-1)$$

are the modified measured input signal and predicted input signal, respectively.

Discussion

An analysis of the gradient vectors of the respective cost functions found that both gradient vectors of the EE method cost function are linear with respect to the parameters. Only the gradient vector w.r.t. parameter *b* is linear for the OE cost function, while the only linear gradient vector for the IE is w.r.t. parameter *a*.

Based on these observations it was proposed to combine the IE and OE algorithms into a "Dual Error" (DE) algorithm that would capture the best attributes of both its components. In essence the IE algorithm will be used to identify the denominator parameters while the OE algorithm will be used to identify the numerator parameters of the transfer function.

Dual Error Method

The Dual Error identification algorithm is the proposed system identification procedure which combines the strengths while avoiding the weaknesses of two single error identification systems. In essence it uses the Output Error e_{OE} to estimate the numerator polynomial $B(z)$ and the Input Error e_{IE} to determine the denominator polynomials $A(z)$.

This new method simultaneously minimizes the vector gradients of the cost functions due to two different errors. The first error is that between the measured output and that predicted by the model while the second error is that between the input to the plant and that predicted by its inverted model suitably modified by $H(z)$. The cost function from the first error will be optimized with respect to the vector gradient in terms of parameter *b* while the cost function from the second error will be optimized with respect to the vector gradient in terms of parameter *a*.

The Dual Error algorithm can be summarized as follows:

1. By using available a priori knowledge of the true system G_0, an initial model G_m is created. To ensure the inverse of the model G_m^{-1} is causal the additional function H is also created.

2. The initial model G_m as well as its inverse $G_m^{-1}H$ is simulated by using the same excitation and measured output as the true system, respectively.
3. The difference between the system output and the model output is used to form a quadratic criterion of the OE algorithm. Similarly a second quadratic criterion is formed by the difference between the system input and the model input produced by the IE algorithm.
4. The model is then modified in order to minimize the quadratic criterion of OE with respect to the numerator parameter b and the IE quadratic criterion with respect to the denominator parameter a.

The Dual Error structure is represented in Fig. 2 and shows clearly the two errors needed for the method.

The primary objective of this method is to minimize the quadratic criterion based on the Output Error e_{OE} in terms of the numerator parameters b. Similarly the quadratic function based on the Input Error e_{IE} is minimized in terms of the denominator parameters a.

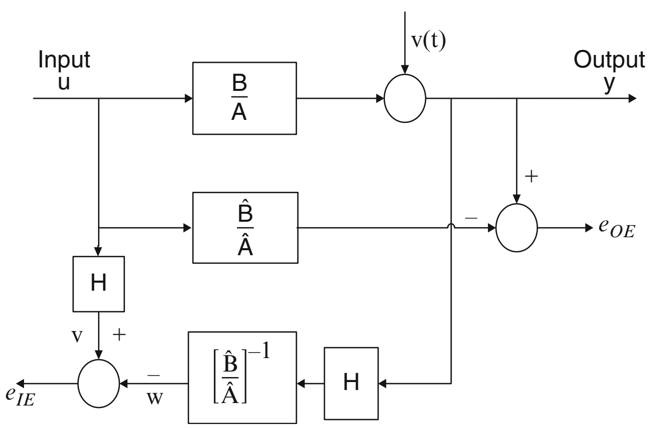

Fig. 2 Dual error structure

Numerical Example

Simulations had been performed to evaluate the performance of the Dual Error method using noisy measurements. The scenarios of noisy output only and noisy input-output were considered and evaluated. In both cases, comparison was made with EE, OE and IE methods for white Gaussian noise.

The unknown system was of first order with parameters as follows: $a_1 = -0.90$ and $b_1 = 0.46$. The noise-free input $u(k)$ was a square wave function which adheres to the requirement of a persistent lively input. The frequency is selected at 1 Hz according to the design analogy. This is acceptable as the sample frequency is 10 Hz and by the Nyquist theorem, aliasing will be prevented for a 50 % duty cycle at a sampling time of 0.1 s.

In order to ensure the inverse of the predicted first order model G_m is causal, it is multiplied by H which is of the form

$$H = \frac{v}{u} = \frac{\beta z^{-1}}{1 + \alpha z^{-1}} \tag{14}$$

The rate of convergence of H(z) in the Input Error is set to be significantly faster than the true system i.e. *speed* = 50 in Eq. (7). The measurement noise σ_y^2 was independent white Gaussian random variables. The sample size was $N = 1000$ and parameters were updated recursively. All results provided were averages of 20 independent experiments.

For the first order system described above Figs. 3 and 4 show the mean square errors (MSEs) for a_1 and b_1, respectively. In addition, Fig. 4b shows e_{IE} as an enlargement of Fig. 4a with a different y-axis as it is much larger than the other errors. As expected, the Dual Error method was superior to the other three single-error system identification methods over a range of measurement noise.

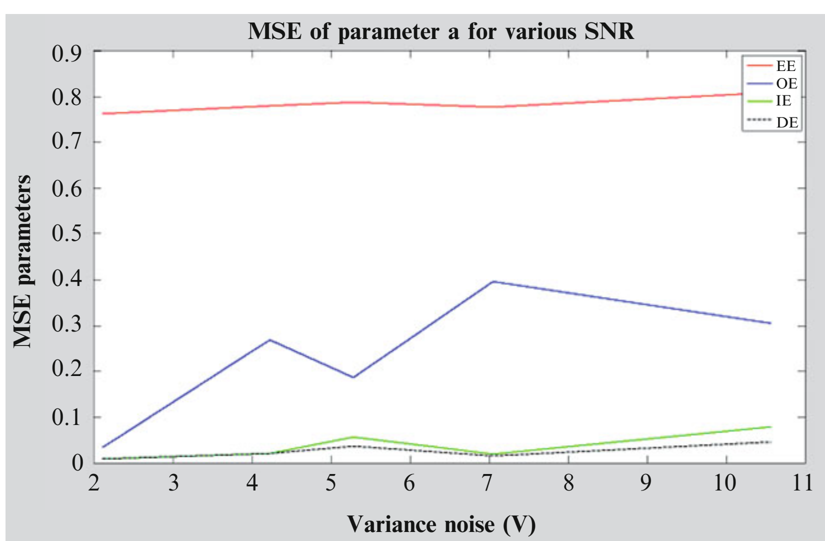

Fig. 3 MSE of predicted parameter a

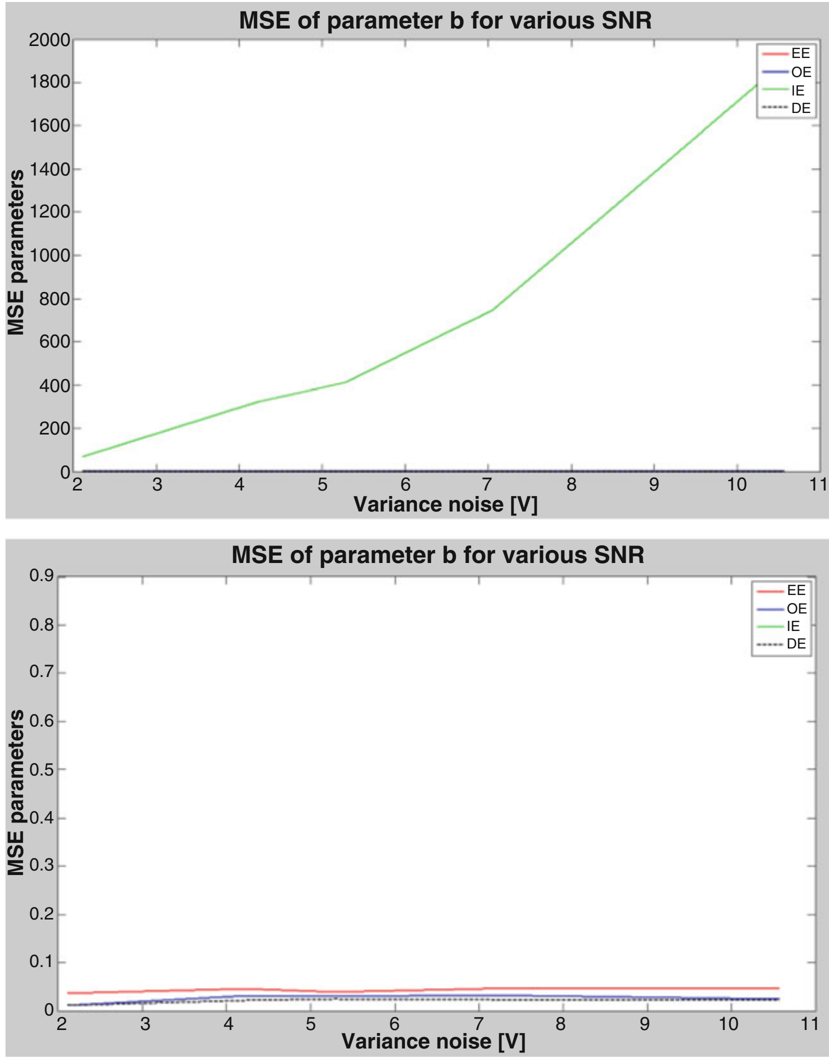

Fig. 4 (**a**) MSE of predicted parameter b. (**b**) MSE of predicted parameter b (enlarged)

Discussion

The IE algorithm has been found to be the most appealing algorithm for predicting the value of denominator parameters for the case of output noise only. This algorithm has the least amount of bias in the identification of the denominator parameters. Similarly the OE algorithm has the least amount of bias in the prediction of the numerator parameters.

An overall view of the results shows that the EE method was consistent in its performance, although it was not the best predictor in every instance. This suggests the robustness of the identification method is improved when both gradient vectors are linear with respect to the system parameters. This overall improvement was achieved and demonstrated with the design and implementation of the Dual Error method.

Practical Implementation

The Dual Error method was then implemented on a physical system, a first order DC motor system set up for speed control. However, since the EE method was constantly inferior to the OE method in the simulation the comparison was only made with OE and IE methods. The same input is used as in the simulation with a sampling time of 0.1 s. The speed of $H(z)$ in the IE is set to be significantly faster than the true system i.e. speed $= 50$.

Predicted Parameters

The expected parameter values of the DC system was determined by several step tests and was found to be $a_1 = -0.9$ and $b_1 = 0.46$. The online prediction of the respective parameters over N $= 1000$ samples is shown in Figs. 5 and 6. In addition,

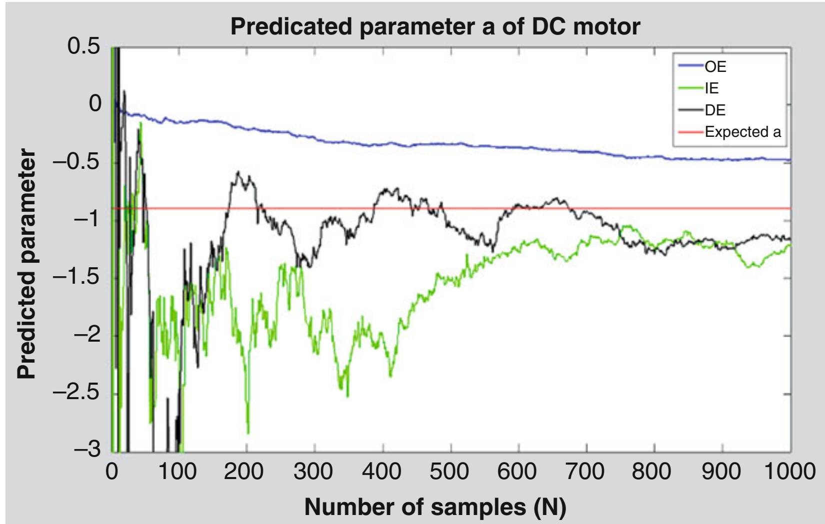

Fig. 5 Segment of the predicted parameter *a* for the DC Motor system

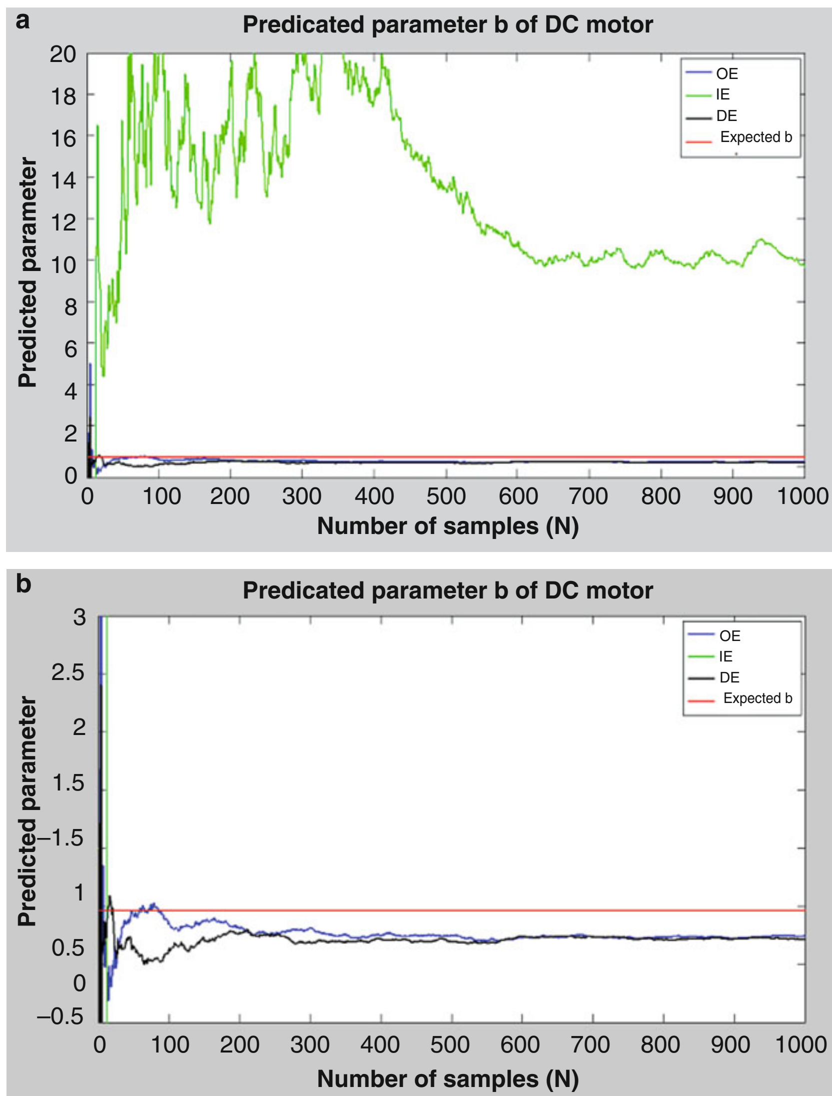

Fig. 6 (**a**) Segment of the predicted parameter *b* for the DC Motor system. (**b**) Segment of the predicted parameter *b* for the DC Motor system (enlarged)

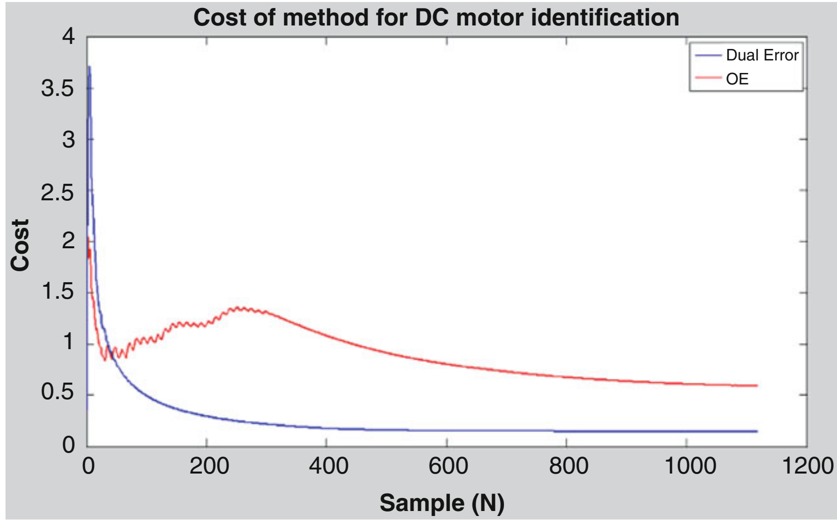

Fig. 7 Cost function of implementing the identification method based on output data

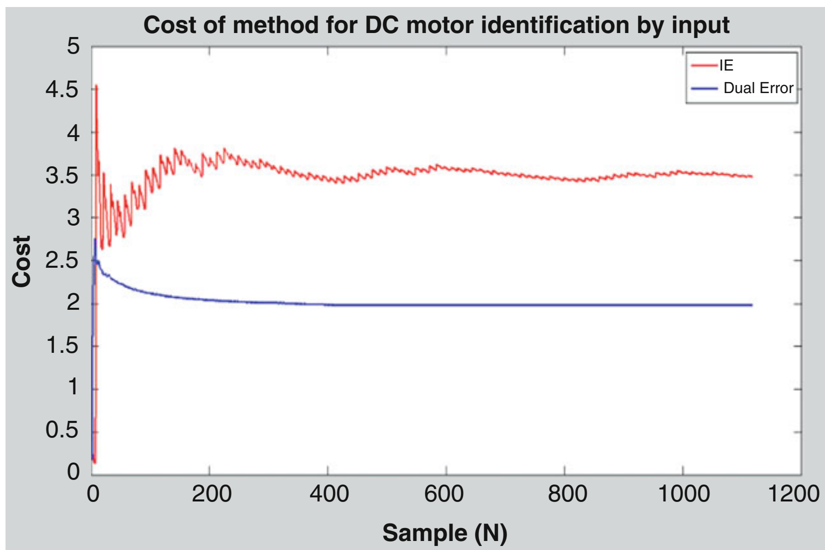

Fig. 8 Cost function of implementing the identification method based on input data

Fig. 6b shows the predicted parameter as an enlargement of Fig. 6a with a different y-axis.

Cost of Identification

The cost function of the residuals of the predicted outputs will be considered. This function is a measure of the performance of the identification algorithm and is the optimization criterion on which to minimize the error between the output of the true system and the predicted model. The cost functions are

$$J(\hat{y}_i) = \frac{1}{N}\sum_{k=1}^{N} \left(y(k) - y_M\left(k, \hat{\theta}_i\right)\right)^2 = \frac{1}{N}\sum_{k=1}^{N} e\left(k, \hat{\theta}_i\right)^2$$

$$J(\hat{u}_i) = \frac{1}{N}\sum_{k=1}^{N} \left(v(k) - w\left(k, \hat{\theta}_i\right)\right)^2 = \frac{1}{N}\sum_{k=1}^{N} e\left(k, \hat{\theta}_i\right)^2$$

The cost of implementing the identification function in terms of the output data is presented in Fig. 7 and updated recursively for each new sample. It is observed that the cost function from the Dual Error converges faster to its minimum and also has a significantly lower final cost value than the OE algorithm. Although the cost function of the OE algorithm does eventually converge, there is an initial increase before the cost is reduced. Again this is due to the initial, rapid change of the predicted parameter.

The cost of the implementing the identification function in terms of the input data is presented in Fig. 8 and was also updated recursively for each new sample. As with the input data the improved cost function that is presented by the Dual Error method in the output data.

Thus, it is concluded that the Dual Error has made a significant improvement on the cost function as compared to the other two methods.

Conclusions

The results from the simulations of the Dual Error, the Output Error and the Input Error are confirmed by the practical implementation of the identification methods on a first order DC motor system.

The Dual Error method demonstrates a significant improvement in the correlation between the measured data and the predicted data in comparison with both the OE and the IE identification algorithms. Furthermore, the Dual Error method improves the cost function and the rate of convergence. This is desirable since it means that the predicted parameters are closely related to the true system parameters.

In comparison with the Equation Error, the Output Error and the Input Error, the estimation of system parameters was significantly improved by the Dual Error method. This was demonstrated in a simulation environment. Furthermore, it can be concluded that it also improves the predictions in a practical implementation. In addition, this is done with minimal complexity in the design of the IE method.

The combination of the Output Error and Input Error optimized of the linear gradient vectors of the respective cost function has been shown to be superior to the component methods. And it is concluded that the novel Dual Error method proposed in this paper is a highly effective tool for system identification.

Acknowledgment The author would like to thank Professor M. Braae for his help, whose patience, guidance and motivation made this project possible.

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On Verification of the Software Development Process

Deniss Kumlander

Abstract
The implementation of the best software engineering process do not guarantee the best result. The ratio of failures is still very high although the formal review of the processes shows no defects. The most common problem is the amount of additional work discovered at the very end of the projects leading either to delays and extra cost or to sufficient decrease in the product quality. All this is unacceptable in the modern rapidly evolving world with a high level of competition and demand to produce software in time with acceptable level of quality. The paper describes how the software process can be examined and verified to ensure that it is not only established, but also followed and all potential risks and uncertainties are resolved right when they occur instead of suppressing.

Keywords
Software engineering • Process • Verification

Introduction

The software development process is a complex set of techniques, which allows us to move from an idea or a short statement of the work to the working software that corresponds to both original specification and current corrected requirements corresponding to the changed business environment. It is a time consuming process which should be well organized to ensure optimal consumption of resources. The modern software development techniques recognize that the communication, continues improvements of the desired goals through periodic demonstrations and resolving uncertainties are extremely important components of the software engineering process if we want to release the right product in the right time without overcoming the initial budget. Working together with customers we involve co-design [1], iterative development [2–4] and other techniques [5] in order to find the shortest path and continuously correct the end product vision. Despite of that the customers' satisfaction reviews show that we are not doing very well since we are still leaving to the end stage a lot of waste [6]. We know that even implementing the most modern approaches to software engineering we still have up to 27 % of all projects reported to fail due unsatisfied customers [7]. Moreover only 20 % of functionality is reported to be used "often" or "always" [8] contradicting with our lean development approaches.

Every company has a dedicated software process that is both following modern practices and suits to the organization of work in that particular company the best. Every time we hope that the end result is an absolute success starting the project and mostly we find ourselves resolving a lot of uncertainties at the final stage, which ruin our budget or time plan. Some authors recognize uncertainties as a kind of risks [9], while others says those are very specific and needs a dedicated framework [10]. One example of such uncertainties are gaps between developed software (features, budget) and customer expectations, gaps in the communication [11, 12] between different individuals and unclear visions of the product. Therefore it is very important to discover the source of such problems by examining not

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_45,

only individuals running the process, but also the entire process since in many cases the troubles are hidden in both components.

In this paper we propose certain techniques that could allow us to verify the process and find stages, persons or channels producing or missing to deal with uncertainties and so creating a high risk of failure. We also revise two cases of companies in order to see efficiency of the proposed technique and potential pitfalls.

Verification Techniques

The goal of the verification process is to revise the software process used currently in the company and either to detect problems, which are not recognized at the moment or to prove that the process works correctly.

Reactive Technique

In many cases companies have already collected a set of incidents, failed projects and so forth and it will not be wise to ignore that collection. The very first thing we should do is to analyze why, despite of the best techniques, the company still have problems. We are not going to discuss in the scope of this paper the case when the current used software development technique is outdated, incorrect or ignorant to certain well-known problems and will assume that this task is already done within that company.

Reactive verification of the process can include the following approaches:

1. Examining the process on presence of anti-patterns: review it and searching for routines and sub-processes, which are well-known to produce problems, hide uncertainties, add extra risks into the software engineering process;
2. Measure the process performance by calculating and comparing metrics of the process or delivered software, i.e. benchmarking. For example, we can evaluate the number of discovered errors in testing, after releasing the project, per LOC (line of code), cyclomatic number, testers and developers involved into the project, complexity of features and try to find out: are the metric exceeds then acceptable level, which indicates problems existence in the process, or not;
3. Review the process by playing it through with different project members to see their opinions, complains;
4. Review the validation process: the typical problem we have seen in our practice in the lack of attention of product owners during the demo process. Knowing that the process of visualization and validation of currently implemented functionality is crucial to ensure that we are building the right product, they often miss to concentrate on details examining only the overall high level view and so discover problems much later postponing or cutting the functionality in the end. Here we need to examine how many features were shown and much later revised and corrected.

Proactive Technique

The main idea of the proactive technique is to stress the process starting from the very first stage of the project instead of waiting for risks to turn into troubles, which later are reviewed and basing on which conclusions on non-working elements done. The verification tests should be planned along building up the software development process to be used in a project although adding them later is also better than not having such at all. Doing that we should revise

1. Software process stages. Every stage should be covered by a test case/test technique;
2. Uncertainties and other process gaps we may have in the project. That is another way of rethinking the process and allows finding gaps between stages, which are not obvious following just stages of the process, or potential problems not implicitly covered by any stage/subroutine of the current process.

After we got a clear view on what kind tests we need we start matching actual test to our needs. The different kind of tests we can use to verify the process are described next and mostly covers all the cases the reader can identify above.

Probing

Of the well-known testing techniques we are going to port to the process of verifying the software development process is an assertion on invalid cases. The idea here is to see how the system coupe with that. In the software development terms—we would like to see that the current process is able to recognize uncertainties on the right stage without suppressing it and so without postponing solving such problem until it is too late or costly to do that.

- Specification stage: it is possible to add into specification contradictory statements, impossible requirements (like a task, which requires solving NP hard problems precisely in a polynomial time). We need to see here—does the team understand the values, the meaning of requirements and co-work on tasks or they would start to realize all this only during the final demo after a month of work. We verify that the team correctly divide the specification into subtasks, no tasks are left without owner and each owner is communicating openly the complexity of tasks to the team and product owners formulating the requirements;

- Design or architecture stage: On that stage we can inject an error by modifying earlier made diagrams in order to see how certain our designers are in the earlier made decisions and would they recognize any errors presenting the approach to other people;
- Development stage
  - The process of assigning and completing tasks: there is always some kind system responsible to assigning and checking progress of tasks. Is that system able to restore in case of distractions? Will the team or manager see that any task is missing (removed by the verifier from their list), moved to the wrong status (completed although nobody worked on that) etc? Will the human mistake be found quickly or only after/during the demo? Do people communicate to each other and know on what stage the project is currently?
  - The process of sizing tasks: The most common problem we have in projects is lack of feedback on more complex tasks than initially estimated to other team members and managers. This happens relatively often and explained by cultural or personal habits, behavioral or social fears. This is very dangerous since the reported and actual progress vary sufficiently and the actual problem is discovered only when we can do very little to change the situation. Of course it doesn't mean that every fluctuation should be reported immediately as estimates are never precise, but sufficient delays are important to evaluate and process. Therefore it is important to ensure that such hiding of actual delays and tasks' sizes would never happen in our team, within our process;
- Quality assurance stage
  - Verification: How do we know that testers do the work in the best way following the best testing practices? We can of course measure the process during the reactive review by examining the overall number of defects reported to helpdesk, but proactive verification is also important. Here we would like to add defects into the software deliberately in order to see who and how quickly will discover those? Do we do the regression and other kinds of tests actually or just following formal and inefficient routines?
  - Validation stage: unlike the verification stage we revise here not the question: "do we build error-free software?", but concentrate on the question: "do we build a right product?". Here we propose to skip during the validation demo certain features or details in order to see how the product owner do their work and align actually implemented software to the requested one? Do we allow uncertainties of none validated tasks to leak in ruining the entire process?
- Documentation stage
  - Knowledge base: Do we always know why one or another decision was made and who is the owner of the decision? Here we do question some features in order to find—do we record our decisions correctly and do we able to find in our protocols answers. This verification will of course require a help from person who knows what to question although random questions to individuals not involved into the process can also identify good cases, i.e. questions nobody is able to answer on. This testing approach will ensure that we do not make decisions again and again and especially that we do not reconsider and decide differently (since we do not know reasoning of the previous one), so rotate in a circle of making, modifying, rolling back our decisions.

Testing Process Flow

One and the very important element of the workflow within the process is the ability to communicate between teams involved into the projects, persons representing different stages of the process (like design team to development team) etc.

- Verifying the external communication: here we need to ensure that information flows correctly from stage to stage and examine potential gaps occurring between stages' borders. Normally different stages are implemented by different teams and therefore it is the most likely place to produce communication gaps. In many cases a simple revision of what was told and what was received can show gaps. In some cases it can be explained also by different background of people involved into the communication and therefore the revision of how the message was understood is very important;
- Verifying the internal communication: it is possible to give to different team members different information in order to find out whether they are communicating at all and the level of details in such examining how quickly they will find such collision in the information. It is important that the team works in joined direction towards the same goal and no tasks are done twice or more;
- Verifying the vertical communication: Here we need to examine the perception of project goals and business values on the lowest level of our hierarchy. Do the people actually implement the requested product, share and understand values and goals?

Stressing

The other verification technique is stressing different aspects or overloading them in order to see the stability of the system. The goal of this part is to ensure that the team will never add uncertainties due stress situations and check that the process is designed to avoid such stresses.

First of all we could add too many tasks to any team member or to the entire team. Do they again able to provide a feedback on absence of ability to implement everything in time or will hide this until the very last minute?

Secondly we should stress aspects of the process like for example the self-organized team autonomies [13]. The self-organized team principle base on three autonomies: the external autonomy, which is the ability of the team to act independently from the external management; the internal autonomy of the team, i.e. the internal procedures of arriving to consensus and so defining the ability to cooperate and discuss; the individuals' autonomy defining the members' individual freedom to pick up tasks and decide how s/he can be most useful for the team.

Study Cases

Description of Cases

In order to verify the process we have contacted two companies, which are not alike. Below we describe some properties of those.

Small and Flexible Company

The company is developing a software system for hospitals and drug stores. It operates in the region with a restricted access from outside for employees and with a sufficient lack of skilled resources. In the result the company outsource different activities to individuals located in other countries and so it is highly distributed. In the result the software engineering process is spanned over geographical regions and communication among individuals representing each stage is restricted. The company follows the agile (Scrum) software development principles. They have two standard products and a set of customer specific modifications. The overall number of employees is—five permanent employees and three consultants. The company is 5 year old and still behaves as a startup in certain cases.

Average Size Software Company

The company is a small division of a large software vendor developing an own financial product, which is consumed by more than 200 large customers. The company is divided across two main locations with a set of consultants all over the world managed by the project team. The product is very much standardized and they release two versions a year following an iterative software development principle to implement each version. The overall number of involved personnel is 45 and the software process more or less the same as in other branches of that software vendor. The overall number of employees in the group is 300. The division of the software vendor we have described above is circa 20 years old, have good established processes and the vision on how software should be implemented.

Lessons Learned

The verification process has been presented to managers of earlier described companies and we have tried, together with them, evaluate the proposed verification by applying it to their software engineering processes in order to see its' benefits or drawbacks. Some of them lead to correcting the overall approaches described above and some of them are comments for the implementation stage and therefore are included into subchapters below.

Small and Flexible Company

In our first study [13] we have identified:

- A lot of knowledge transfer related issues: sometimes team members were not informed on what others do;
- Problems with defects added by the verification team, missed by the process and remained in the final product, i.e. missed to remove by the verification team;
- Absence of re-verification: identified problems were communicated and fixed, but after sometimes the process was again simplified and problems reappeared.

During the new cooperating study we have implemented the described above extended model, which is much more systematic and have identified leaks in nearly every component of their software development process except the validation phase, which can be explained by high attention of the owner of the startup to the product and every aspect of it. From the owner point of view, the process will help him to organize the co-work within the distributed team much better as it adds a possibility to ensure that the best practice they use is actually followed.

Average Size Software Company

During our first study [13] we have identified that the process was in place only formally producing a lot of troubles at the end of the process. The new implementation of the verification process has added some sufficient details to that knowledge and below we state the most interesting of them:

- The validation process was not detailed enough. Although product owners were clearly willing to do the work, they were overloaded with other tasks which was leading to the never ending story of correcting and doing extra work at the end of the implementation phase since only then the formal project acceptance was done discovering actual problems;
- The knowledge base was incomplete as the attempt to follow zero documentation agile practices was either incorrectly understood or implemented. In the result the

communication between departments wasn't smooth as everybody suspected that the other team does not follow earlier made decisions.

Conclusion

In this paper we have expanded our early studies of the uncertainty management foundational principles and test based verification of software process.

The high ratio of failed or nearly failed software projects clearly shows that it is not enough to establish a software engineering process even if it is a copy of the best advices in that field. It is important to follow that process and ensure than no components are missing and no risks, uncertainties or miscommunications are done. It is impossible to be sure about that unless we do verify the development model by techniques proposed in the paper allowing us to obtain certainty that every member of our team not only informed on the process, but also share the goals and follows the essence of it. Without such verification process we will be forced again and again eliminate the consequences of problems instead of dealing with roots of those.

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Control-Flow Checking Using Binary Encoded Software Signatures

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Abstract

Correct execution of a program source code is an essential part of the modern information systems. Due to various external causes, the process execution can fail and lead to unpredictable consequences. Proposed solution detects control-flow errors caused by a faulty execution of jump instructions, by the means of program execution controlling technique based on inserting software signatures to a source code. In this paper we are proposing a new algorithm for control-flow checking called CFCBS.

Keywords

Control-flow • Fault tolerance • Software signatures

Introduction

Execution of a program source code is one of the fundamentals of each information system. There are some situations, when it can become faulty, either permanently or only as a one-time experience. One of the possible failure sources is a radiation, which can cause transient hardware failures leading to an incorrect program execution. In the area of information technologies, a correct execution of computer programs is considered a matter of course and any fault is considered inadmissible. Faulty program execution can cause many problems, especially with programs those are performing mathematical tasks, or those used for controlling or regulating various machines. Failure of such program, for example of an aero-navigation system, can lead to disastrous consequences. Due to its key role in the software field, the reliability of a program execution should be among the main interests of each software-developing organization. Therefore the detection of failures plays an important role in securing the process reliability. Our solution deals with detecting control-flow errors with the aim on an incorrect execution of jump instructions, which is an enormous risk in the majority of software systems. Almost every program code contains branch instructions or function calls, which are translated into jump instructions in the low-level programming languages. According to [1, 2], more than 70 % of all transient faults lead to control-flow errors, which are basically incorrectly executed jump instructions. Detection of this type of errors is called control-flow checking and it can be done either by hardware or software means. Hardware control-flow checking requires a special hardware device called Watchdog processor, which is checking the control-flow of a program executed by a separated processor. Software solutions are usually based on a technique that uses special signatures those are being inserted into the source code in the time of compilation, or before. Based on these signatures and a checking function it is decided in the runtime whether the execution is faulty or not. Two of the most popular software control-flow checking algorithms are CFCSS and ECCA; most of the other software algorithms are based on these two. While CFCSS is an implementation using a low-level language and is using xor (an exclusive or) as its validating function, ECCA is a high level implementation using prime numbers and modulo as a part its checking function. Our solution is trying to merge the advantages of both of these algorithms into a new, more effective one.

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DOI 10.1007/978-3-319-06773-5_46,

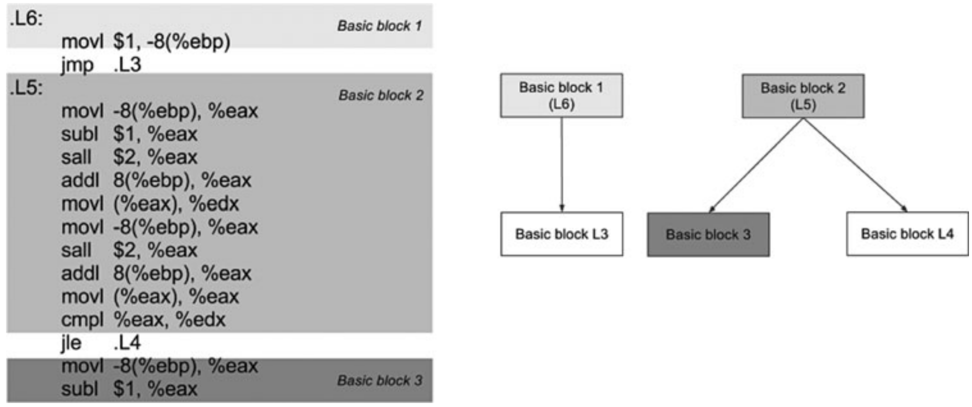

Fig. 1 Example of a control-flow graph creation

Proposed Algorithm CFCBS

In order to insert control-flow checking signatures into the program source code, the control-flow graph has to be created first, as shown in Fig. 1. As a part of our solution we developed a program that parses a program source code (currently ×86 assembler files with AT&T syntax are supported). Based on a regular expression driven parsing it searches for entry and exit points of functions, jump instructions and function calls. It identifies all of the basic blocks and edges between them and finally builds an internal representation of the program control-flow graph.

The proposed algorithm assigns two types of signatures to the identified basic blocks—ID and PREV. In the first step of the signature assignment are basic blocks divided into two groups as following:

- First group contains each basic block, which has exactly zero or one predecessor.
- Second group contains every basic block, which has more than one predecessor.

Based on these two groups we can divide all of the identified basic blocks into two main categories, which we will solely for the purpose of this document call Category A and Category B. The basic blocks are assigned to these two categories according to the following rules:

- Category A contains all of the predecessors of the blocks from the first group. On the Figs. 2 and 3 are blocks from this category marked with a lighter shade of grey.
- Category B contains all of the predecessors of the blocks from the second group. On the Figs. 2 and 3 are blocks from this category marked with a darker shade of grey.
- If a basic block B, according to the rules above, belongs to both Category A and B, it will beassigned to Category B.

Second step is to assign ID to each basic block, as can be seen on the Fig. 2. The ID is a unique identifier of the block, and is used to determine the correctness of the execution of the jump instructions. The rules used for ID assignment are designed for each ID to be unique and are as follows:

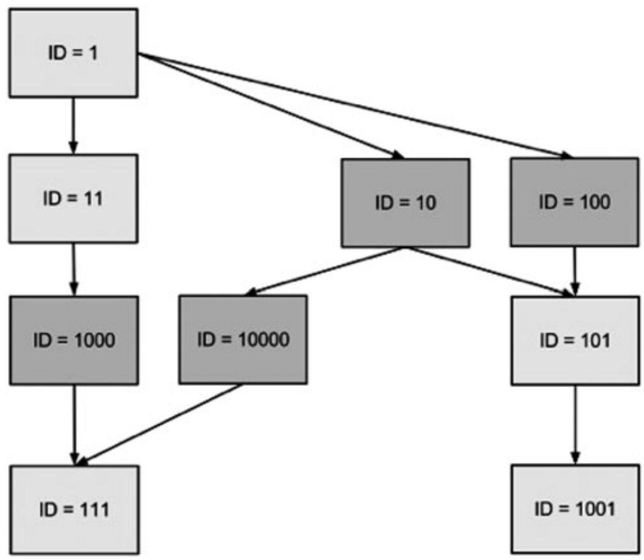

Fig. 2 Assigning ID to each basic block

- Each basic block from Category A is assigned an ID that is odd, beginning with 1 and ascending.
- Each basic block from Category B is assigned an ID that is a power of 2, starting with 2 and ascending.

The last step is assigning the PREV signature for each of the basic blocks, as can be seen on the Fig. 3. PREV holds the information about the legal jumps to the block to which it is assigned. PREV is a result of performing a logical OR operation on the IDs of all of its predecessors.

We created categories A and B in order to decrease the memory demands of the algorithm, since our solution is primarily based on assigning powers of 2 as IDs. Since the basic blocks marked as Category A blocks are the only single predecessor to all of their successors, there is no need to store more than one predecessor in their successor's PREV signature. Therefore, to decrease the number of bits required, they are assigned odd numbers as an ID.

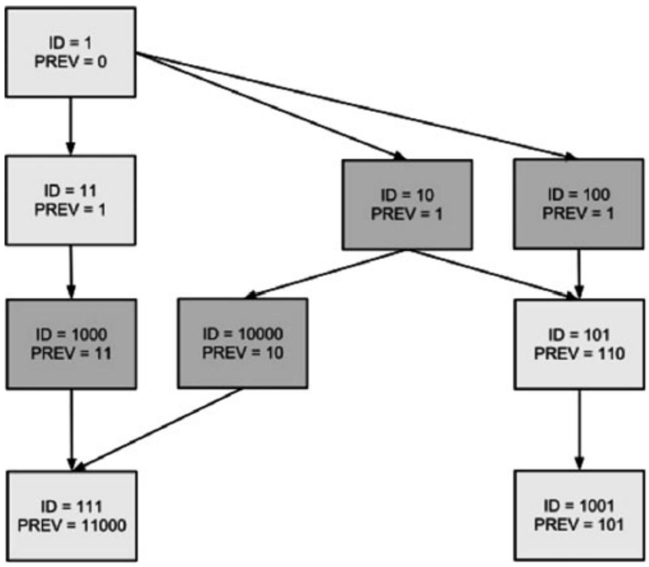

Fig. 3 Assigning PREV to each basic block

Signature Checking Using CFCBS

The proposed control-flow checking algorithm CFCBS is based on performing bitwise operations, due to their high efficiency and low calculating demands on the processor. The checking takes place at the beginning of each basic block. The algorithm consists of a few basic steps:

1. The variable LAST contains the ID of the last basic block that was executed. When enteringa basic block, the correctness of the control-flow is checked as follows:
   a. If the value of the current block's PREV variable is odd, we compare PREV and LAST. If they are not equal, the jump was illegal.
   b. If the value of the current block's PREV variable is even, a logical and is performed on the LAST and PREV values. If the result is equal to 0, the jump was illegal.
2. The variable LAST is set to the ID of the current block.

In the case of detected incorrect execution of the program, the execution is stopped and an error is detected.

Blocks checking the correctness of the program execution are inserted into the original program's source code after creation of the control-flow graph and assignment of the signatures to the identified basic blocks.

A control-flow checking blocks are situated at the beginning of each basic block. There is also a checking block right after each function call used for validation of the function returning point.

Conslusions and Further Work

The proposed algorithm CFCBC was designed with an aim on combining the advantages of the two existing ones—CFCSS and ECCA.

We plan on developing a more efficient concept of storing the ID and PREV. Current concept uses a 32 bit integer for storing the ID and PREV values, in the future we plan to enhance the solution so, that it will be able to store more values with a lower memory demand, using a coding scheme or other means.

We also intend to implement the proposed algorithm as a plug-in to the GNU Compilers Collection. In the process of compilation of a source code, GCC creates its own control-flow graph representation of the program that is being compiled. GCC plug-in has an access to GCC's internals, which can be used for insertion of the signatures and checking blocks directly into the intermediate pseudo code maintained by GCC during compilation, which would give us a fair amount of flexibility through various architectures and programming languages.

Acknowledgment This work was supported by the Grant No. 1/1105/11 of the Slovak VEGA Grant Agency.

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Transformation of the Software Testing Glossary into a Browsable Concept Map

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Abstract

Authors propose a transformation method of the glossary "Standard glossary of terms used in Software Testing" created by ISTQB document into a basic concept map. By applying natural language processing techniques and analyzing the discovered relations between concepts the most essential aspects of the software testing domain are elicited and integrated. As the result a browsable concept map is created. Browsable concept map can be used as a learning support tool.

Keywords

Software testing glossary • Natural language processing • Browsable concept map

Introduction

Successful learning of any topic is not possible without the understanding of the key terms and their relations relevant to the particular domain. As a learning support tool a glossary of terms can be used. Glossary is a semi-structured text document that contains domain concepts and its explanations. Some relations between concepts are defined in an explicit way.

The drawback of a glossary is the difficulty to easy conceive the surroundings of a term—the helping aids, such as: see, see also, synonyms, acronyms etc.—are time consuming to inspect.

Authors have developed a semi-automatic transformation method of a glossary into a browsable basic concept map. The browsable concept map allows the learner to navigate from a particular concept to its corresponding concepts, explore the definitions of the concepts "on-the fly". The complexity of the domain is managed by the authors applying natural language processing techniques and elicitating the most essential aspects of the domain.

As the domain for research the authors have chosen the software testing. Software development is very complicated domain and a significant part of human resources is being spent for software testing. An authoritative glossary of the software testing is Version 2.2 of "Standard glossary of terms used in Software Testing" issued on October 19, 2012 [1]. This glossary is produced by the "Glossary Working Party" of International Software Testing Qualifications Board (ISTQB) [2]. Glossary accumulates terms and explanations from the most significant sources in the software testing field. Contribution was made from testing communities throughout the world. The glossary in year 2012 consists of 800 entries (724 entries in year 2010).

Current work is an expansion of the work [3] done by the authors—semi-automatically generating a lightweight ontology from the year 2010 version of ISTQB glossary [4].

Development of Concept Maps

A concept map is a diagrammatic method of knowledge representation developed by Joseph D. Novak in 1972 in educational setting researching changes in children's knowledge of science [5]. Concept mapping is being used nowadays in many different domains—commerce, governance, ecological management, organizational learning etc. [6]. Concept

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_47,

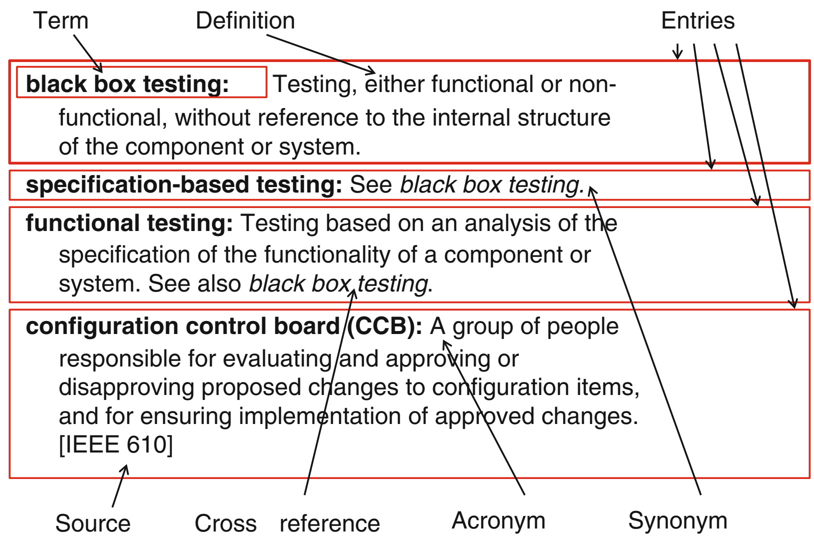


Fig. 1 Structure of the glossary

map usually consists of hierarchically organized concepts and propositions about concepts. Concepts are defined as "a perceived regularity in events or objects, or records of events or objects, designated by a label; propositions are statements about some object or event in the universe, either naturally occurring or constructed" [5]. Concepts in diagrams are represented as circles or boxes, propositions are represented by named lines connecting two or more concepts.

Concept mapping has helped learners to learn, there are evidences of fruitful use of concept mapping in geology students studies, teamwork improvement, document imaging system usage tutoring [6].

But, how to develop a meaningful concept map? How to discover the essential concepts, how to link the concepts by propositions? For manual development of a concept map a procedure originally proposed by J.D. Novak can be used: construct a Focus Question (problem to be solved), identify the key concepts, rank order the key concepts, write the propositions, build the cross-links, revise the concept map. Routine work for map drawing can be done using an appropriate computer software, for example, CmapTools.

Manual development of a concept map involves difficult creative subtasks for the learner—concept discovery, linkage discovery. Therefore researchers have worked towards automatic or semi-automatic concept map development. Crucial for the success is the ability to process automatically the data about the relevant domain. As success stories can be mentioned the concept map creation from the dialog between the teacher and the learner [7], the dance structure extraction from the 3D motion data [8], the concept map creation from the OWL ontology [9], the processing of documents written using morphologically rich languages [10].

In this paper authors demonstrate how a concept map can be developed automatically by transforming the data about a particular domain—the software testing. The data to be processed is a semi-structured text document—glossary. The resulting concept map is browsable, allowing the learner to navigate quickly between essential concepts and getting the definitions of the concepts "on-the-fly". At a particular moment the learner sees only relatively small surroundings of a concept.

Glossaries and Their Usage

A glossary is a semi-structured text document that contains descriptions of domain concepts and links among them.

Structure of a Glossary

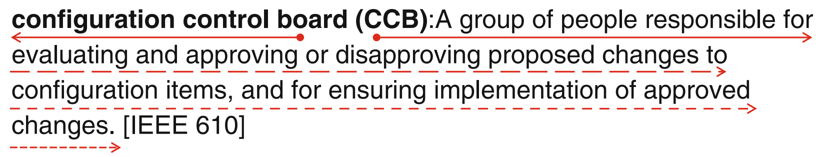
A glossary represents in textual form the information about a particular domain. A glossary usually contains domain concepts, relations among concepts, explanations in a semi-structured way. Some relations are explicitly named.

Let us have a closer look at the chosen glossary—ISTQB glossary [1]. The glossary consists of entries. Each entry has two parts—the term and the definition. The term is the concept what is explained (e.g. 'black box testing') in the first entry in Fig. 1 and the definition is the text that follows after the term and the delimiting colon symbol ':' (e.g. 'Testing, either . . . or system.' in Fig. 1).

Usage of Glossaries for Building Ontologies

A glossary as a text document contains semi-formal information about the concepts and relations among them in a

Fig. 2 Glossary entry analysis



particular domain. Therefore a glossary resembles by its content a more formal representation of domain knowledge—an ontology. Not surprisingly many researchers have proposed the usage of glossaries for building ontologies.

The development of an ontology from a glossary is a known approach, the general idea and methodology of this approach in a simplified way are given in [11]. But the whole potential of this approach it is not yet exploited.

In [11] the authors propose parallel construction of a domain ontology and construction of a complete domain terminology. The methodology consists of nine phases: Clustering, Saturation, Relationship identification, Disambiguation, Class grouping, Conceptual modelling, Schema representation, Ontology representation, Annotation. Each phase is explained, the input and output is defined. The methodology is demonstrated by an example—implementation of a project for definition and representation of a standard terminology for orthodontics (medical domain) based on the orthodontic glossary. All phases are performed manually and automatization is mentioned for the future research.

More detailed description of a methodology for building ontologies from glossaries is given in [12]. The methodology is applied to obtain the ontology OntoGLOSE from the "IEEE Standard Glossary of Software Engineering Terminology". The glossary defines approximately 1,300 terms. The ontology created includes 1,521 classes and 324 properties or relationships. The ontology building uses in some phases semi-automatic steps and semi-automatic linguistic analysis. Unfortunately the paper does not contain precise information what was automated and how it was implemented. Similar to the authors of orthodontics ontology [11] authors of OntoGLOSE are planning to use the obtained ontology to unify the vocabulary.

The ontology development process based on documents is studied by several scientists. A comparative analysis of aspects of ontology development allowing the automatic construction and exploited software for automatic ontology generation is given in [13]. The most difficult task at first steps is the finding of the most important concepts, categorizing them and creating of a meaningful hierarchy and relationships between concepts. Methods for data clustering can be used, for instance. TaxGen Framework can generate a taxonomy from a collection of previously unstructured documents using data mining approach [14].

Elicitation of Significant Domain Aspects

The knowledge about a particular domain can be perceived in many ways depending on the learner's needs and background. We call some parts of the knowledge—aspects. An *aspect* is a concept together with links to other concepts. The ONTO6 methodology [3] makes use of the 6W framework: What, Where, When, How, Why, Who and suggests to find the most significant aspects by analyzing the occurrences of terms in input document and setting the threshold for the inclusion in the list of significant aspects. An aspect allows to see only the relevant part of a domain. As the name of the aspect we use the essential word used to elicitate the aspect.

Finding Significant Domain Aspect Names

Let us inspect the sample entry in Fig. 1. From this example we can deduce the semantic structure of an entry in this glossary (Fig. 2):

- The most semantically significant word of a term is at right hand side, usually it is the last word of a term;
- The most semantically significant word or words of a definition are located at the beginning part of a definition.

The detection of the essence of a particular domain is easier by using glossaries instead of an arbitrary text due to the possibility of exploiting the structure of a glossary.

We apply an improved form of the method of extraction of the most significant words from a document in the form of a glossary [3] by discarding some elements of glossary entry, such as, source, cross-reference, acronym, synonym. We assign a *weight* to each word from the glossary. The total weight of the word is the sum of the word weights in each entry.

The closer a word is to the border between the term and the definition, the weightier it is. Let us number all words in a term from the right to the left starting with 0, and let us number all words in the definition from the left to the right starting with 0. Let us call the word number—the *word_index*. The weight of a word is the sum of all weights of all instances of this word in an entry, and weight of the word instance is calculated by the formula $2^{\text{-word\_index}}$.

Before weight calculations it is advisable to make a normalization of each entry, for instance, to extract and delete acronyms from the term; to delete all punctuation marks; to replace uppercase letters with lowercase ones if

Rank	Count	Word	Word	Weight
1	512	**test**	**testing**	**228.49**
2	345	**testing**	**test**	**120.07**
3	180	**software**	*tool*	**57.54**
4	137	**system**	**software**	**50.67**
5	125	**process**	**process**	**49.26**
6	118	**component**	*analysis*	**33.69**
7	87	*product*	*capability*	**29.71**
8	77	*based*	*technique*	**27.03**
9	75	*design*	**coverage**	**26.35**
10	75	*tool*	*based*	21.17
11	68	**quality**	**quality**	19.53
12	67	*technique*	*set*	19.21
13	60	*execution*	*management*	18.61
14	60	**coverage**	**condition**	18.05
15	59	*analysis*	**component**	17.43
16	58	*data*	*model*	17.31
17	54	*requirements*	*percentage*	16.25
18	52	**condition**	*box*	15.25
19	52	*control*	**risk**	14.86
20	51	*development*	*document*	14.57
21	49	*management*	*black*	14.56
22	48	*level*	**system**	14.37
23	46	*set*	*report*	14.01
24	44	*model*	*product*	13.85
25	42	*activities*	*design*	13.68
26	42	**defect**	**review**	13.32
27	40	**project**	*approach*	13.07
28	40	**decision**	**integration**	12.42
29	40	**risk**	**case**	11.60
30	39	*user*	*development*	11.50
31	39	*determine*	**result**	11.43
32	39	*phase*	*criteria*	10.77
33	38	*specified*	*white*	10.56
34	34	*capability*	**statement**	10.54
35	34	**result**	**path**	10.53
36	34	**performance**	**specification**	10.39
37	33	**code**	*control*	10.35
38	33	**input**	*degree*	10.08
39	33	**specification**	*type*	10.03
40	33	*time*	*level*	10.00

Fig. 3 Result of word weighting process

the word is not an acronym; to delete all stop words (we use a 1,200 stop word list compiled from public sources).

For instance, the weight for the word "testing" in the entry "**functional testing**: Testing based on an analysis of the specification of the functionality of a component or system. See also *black box testing*." is sum $2^0 + 2^0 = 2$. Remark: we do not use the cross-reference part "See also *black box testing*." to calculate the weights of words. The word "analysis" is at third position after extracting of stop word and has weight $2^{-2} = 0.25$.

We calculate the weight for each instance of a word and sum weights for any word. The result of words weighting process is shown at Fig. 3. On the left side (count-rank list) we include the result of traditional word counting that is used in many methodologies. On the right side (weight-rank list) we include the result obtained by weight calculations. For both methods we show the top 40 words. Word, which is not in both categories (taking into account only first 40 words), has a grey background. The word in bold is a term of the given glossary, and the word in italic is not a term. A word in the count-rank list is connected by the line to the same word in the weight-rank list. Solid lines are used for the weightiest words. Dashed lines are used for other words.

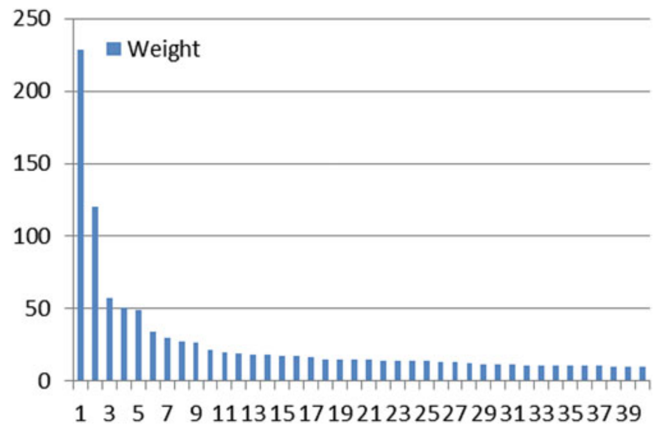


Fig. 4 Distribution of words by weights

The distribution of words by their weights is shown in Fig. 4. The most significant words in the whole domain are: *testing, test, tool, software, process, analysis, capability, technique, coverage*.

Creation of the Aspect Graphs

An *aspect graph* is a set of *nodes*, which corresponds to terms, and *edges* (*relations*) among them. At first we find all entries that belong to a given aspect according to the aspect word. Then a graph is created, any two nodes are connected by edge if a relation between corresponding terms is discovered. Afterwards graph is simplified by reducing nodes (merging of nodes that correspond to synonym terms) and by reducing edges (deleting excessive relations assuming that all relations are transitive). The details of algorithms are described in [3].

The first iteration of an aspect graph contains only unnamed relations. The types of relations have to be added during next iterations. Authors have not done it yet, next iterations are needed to obtain more accurate concept map.

As a sample of domain aspect graph an aspect graph for word "specification" is given in Fig. 5. All related synonyms are collected into one node and are separated by the symbol '='.

Many aspect graphs are included in complimentary material to the paper, available on our expanding site [15].

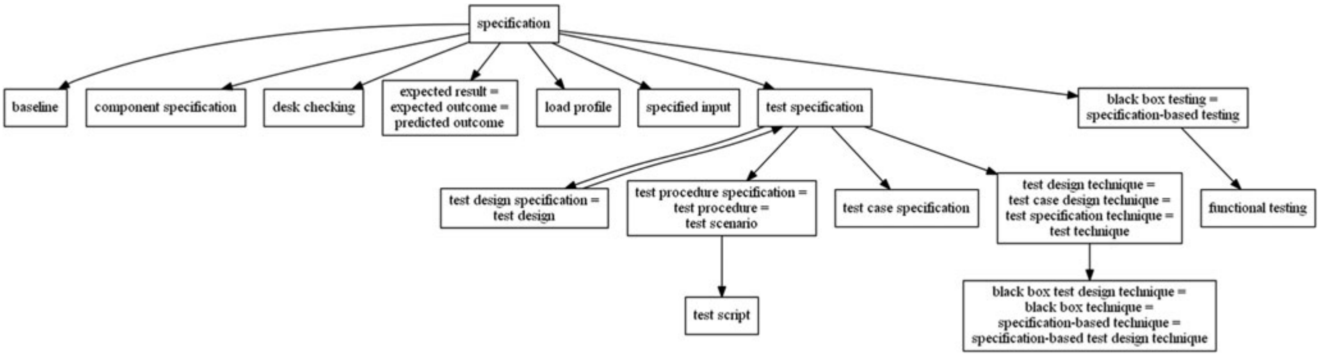
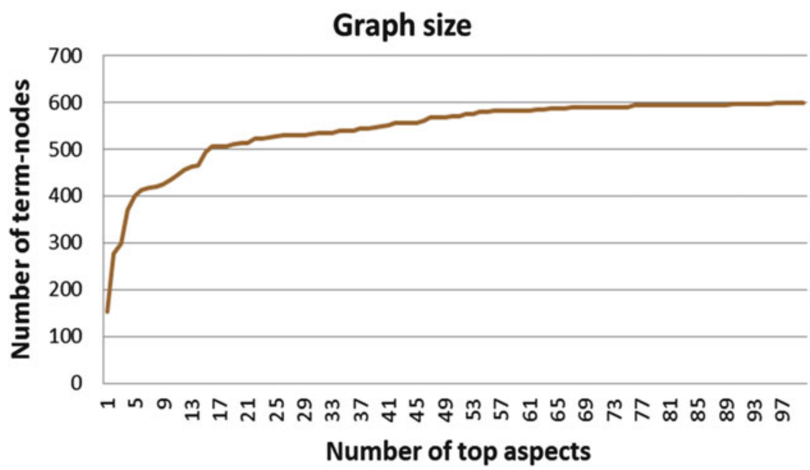


Fig. 5 Aspect "specification"

Fig. 6 Coverage of glossary depending on number of top aspects



Results

We generated domain aspect graphs for each word that has the weight at least 2 and for any word that is a term consisting of exactly one word. Let us look at statistics of this generation. The software testing glossary consists of 800 entries. Six entries have two different definitions. Since glossary contains entries that are descriptions of synonyms, we collect all related synonyms into one node. For terms that have alternative definitions, we create a node for each definition.

As the result we obtained 778 unique aspect graph nodes. Each node can belong to many different aspect graphs. Among these 778 nodes there were 137 nodes containing synonyms; 471 nodes—corresponding to a term with exactly one word; 170 nodes—corresponding to significant words revealed by the words weighting process. We call the node that belongs to the first two groups a *term-node*. Total number of *term-nodes* is $137 + 471 = 608$. A node corresponding to a significant word we call a *word-node*. Total number of *word-nodes* is 170.

The aspect graphs created from the weightiest nine words contain 70 % of all term-nodes if we merge all graphs into one consolidated graph. The Fig. 6 illustrates how the top 100 aspects incorporate *term-nodes* into the corresponding aspects graphs.

Prototype of a Browsable Concept Map

We chose to generate the aspect graphs for each word that has the weight at least 2 and for any word that is a term consisting of exactly one word. The number of such words and respectively aspect graphs is 325. We merged these graphs together eliminating duplicates of nodes and edges. Resulting graph contains 778 nodes and 1,954 edges.

To grasp the whole graph at once is impossible even if we use a very large monitor. We propose to browse through the graph and look at small focus-graph. A *focus-graph* is understood as the node that is in our focus, the nearest nodes, and edges among these nodes. By concept *nearest node* we label the node that is achievable from the focus node via some edges or otherwise—from the nearest node to the focus node.

Various strategies can be established for getting the nearest nodes. For prototype we have chosen very simple

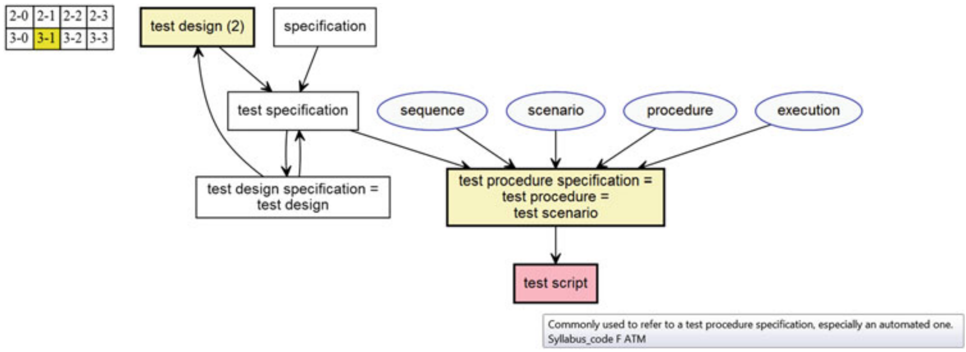


Fig. 7 Focus-graph for node "test script"

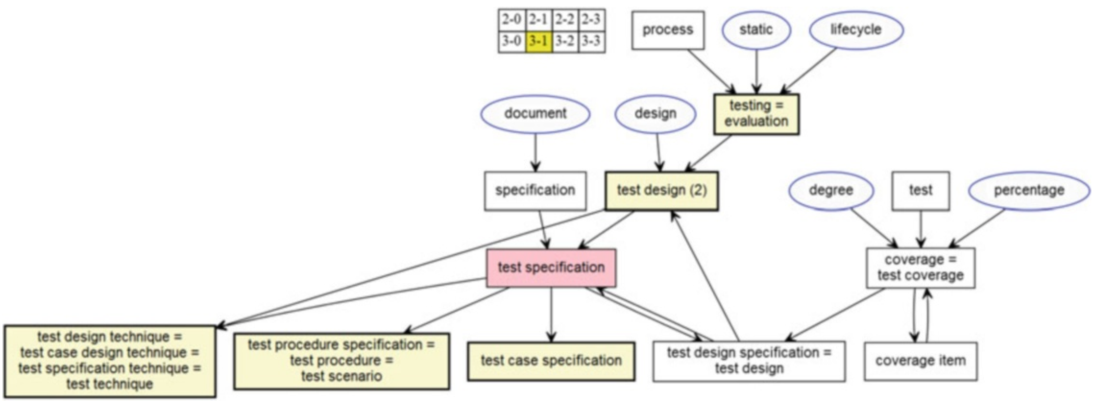


Fig. 8 Focus-graph for node "test specification" (IN = 3 and OUT = 1)

strategy with two parameters—*IN* and *OUT*. IN determines the maximum length of the path from the nearest node to the focus node. OUT determines the maximum length of the path from the focus node to the nearest node.

A sample of a focus-graph is given in Fig. 7 with the node "test script" in focus. The node in focus has red (gray in gray-scale figure) background. A *term-node* is shown as a box, and *word-node* is shown as an ellipse. For this focus-graph we used parameters IN = 3 and OUT = 1 (for instance, path from "specification" to "test script" is 3, and it is a maximum length for IN type path).

Our prototype works with internet browsers that support SVG file format. If mouse cursor is located on a node text, then a tooltip appears (in Fig. 7 the mouse is located on the node "test script"). A tooltip displays the definition from the glossary for the respective term.

Each node name provides a link to the corresponding focus-graph where the node located under the mouse cursor becomes the focused one. For instance, by clicking on "test specification" (Fig. 7), we navigate to the focus-graph shown in Fig. 8.

We have tried three variants for creating focus-graphs. At first we used IN = 2 and OUT = 2 (Fig. 9). For many nodes, which serve as the basis for the top level aspect, focus-graphs are too big to understand them.

Second variant was with parameters IN = 2 and OUT = 1 (Fig. 10). In this case focus-graphs often are small and do not give enough information about related concepts for the focus node.

Third variant uses parameters IN = 3 and OUT = 1. Graphs in Figs. 7 and 8 are constructed with these values for parameters IN and OUT. We consider these values as preferable compared with previous variants.

Conclusion

Authors have developed a browsable concept map of software testing domain providing for the user access to the concept definitions and enabling the navigation to related terms. Authors have shown how such a browsable concept map can be automatically generated from a software testing glossary. Changes in the glossary can be semi-automatically taken into account for the concept map generation. Manual work is still needed for entry text cleaning, for configuration of entry part type recognition. Algorithms developed by authors are applicable to arbitrary glossary. The result is dependent from the language of the glossary—English language is convenient, authors have obtained a sensible result without deep morphological analysis.

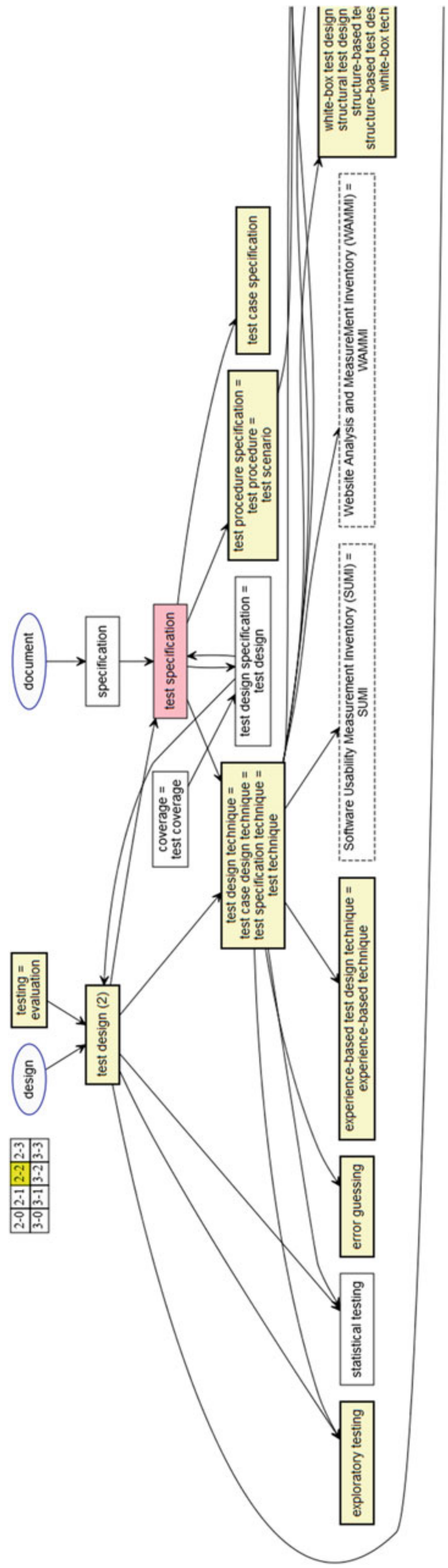


Fig. 9 Focus-graph for node “test specification” (IN = 3 and OUT = 1)

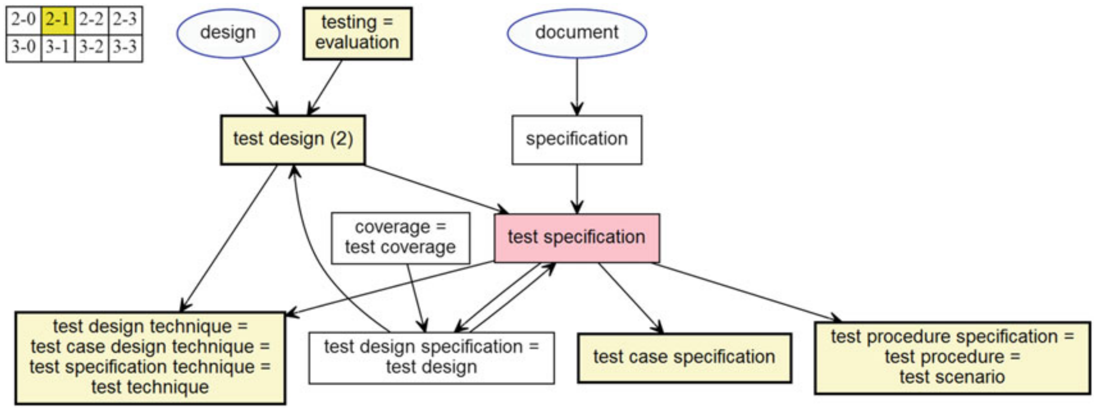


Fig. 10 Focus-graph for node "test specification" (IN = 2 and OUT = 1)

Additional relations between terms are detected by our algorithms. During next iterations of concept map generation the types of relations have to be added, but the initial concept map already allows conceive the surroundings of a term in a browsable way.

Some directions for further work—detailed morphological analysis; better graph deployment; various strategies for improving the building of term surroundings; better visualization (colors, form, information); facility to edit the map; evaluation of the results by the domain experts.

Complimentary material to the paper, containing top aspects, browsable aspect graphs, etc., is available on our expanding site [15].

Acknowledgment The work is partly supported by the European Social Fund Project No. 2009/0216/1DP/1.1.1.2.0/09/APIA/VIAA/044. This work has been partially supported by the Latvian National Research Program Nr. 2 "Development of Innovative Multifunctional Materials, Signal Processing and Information Technologies for Competitive Science Intensive Products" within the project Nr. 5 "New Information Technologies Based on Ontologies and Model Transformations".

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Metallographic Image Processing Tools Using Mathematica Manipulate

Sara McCaslin and Adarsh Kesireddy

Abstract

The objective of this research is to present digital image processing (DIP) modules specifically designed for use with metallographic images. The goal of the application is to make digital processing algorithms accessible to users with limited background in programming, a specific interest in metallurgical applications of DIP, and the need to setup interactive, easily modified modules.

Keywords

Digital image processing • Metallography • Image processing • Mathematica

Introduction

The term "image processing" refers to the transformation of one image into another image and may include operations such as noise removal, color scale modifications, or feature enhancement. Note that the term "image analysis" is similar to image processing but may result in a data set that is not another image [1]. An image can be viewed as a function, $g(x,y)$ where x would be the horizontal position of a pixel, y would be the vertical position of a pixel, and $g(x,y)$ would be either the grayscale level associated with the pixel or the color intensity.

There are a variety of digital image processing software packages available, ranging from the well-known Adobe Photoshop family to the free yet powerful LISPIX package from the US National Institute of Science and Technology Materials Measurement Laboratory [2]. Other commonly used tools include Add-on packages for mathematical software such as Matlab Digital Image Processing toolbox [3] and Maple's Image Tools package [4]. This research focused on using the built-in image processing capabilities of Wolfram Mathematica 8. Mathematica was chosen because it combines image processing algorithms with the option of creating interactive, live modules that can be shared and modified by others [5].

Metallography studies the structures and properties of materials at the microscopic level. Addition of a digital camera to a metallurgical microscope provides digital images whose analysis can be automated using digital image processing.

Pre-processing

Grayscale Conversion

The first step in preprocessing digital metallographic images is converting the original image to grayscale. This reduces the complexity of filtering, edge detection, and noise removal procedures by reducing the pixel data to just one value (gray scale intensity) as opposed to three values (red, green, and blue intensity). Grayscale values are commonly calculated as a weighted average of the red, green, and blue color intensities [6].

Histogram Normalization

Histogram normalization can be used to ensure that the pixel values in an image cover the entire pixel value range.

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_48,

This improves the image contrast evenly distributing the gray level intensity of the pixels. The goal of histogram equalization is to cause the gray values in the image to be uniformly distributed in the output histogram. Values g_{max} and g_{min} are the minimum and maximum gray levels, respectively, g represents the input imagery, integer values i and j represent the location of the pixel, and $P(g(i,j))$ is the value of the desired cumulative distribution function.

$$\hat{g}\,(i,j) = (g_{\max} - g_{\min})P(g(i,j)) + g_{\min} \tag{1}$$

Noise Reduction

Background noise is another issue with digital metallography. When filtering noise from images, the assumption is that any single pixel in an image is much smaller than the details of interest. This implies that neighboring pixels most likely belong to the same phase.

Various methods have been used to eliminate noise, including median filters [7, 8] and modified mean filters [9]. A mean filter can be represented by Eqs. (2) and (3), where $h(p,q)$ is the averaging mask and $g_L(i,j)$ is the low-pass version of the input image. In short, the gray level at $g(i,j)$ is replaced by the average over a $(2m + 1) \times (2n + 1)$ rectangular neighborhood.

$$g_L(i,j) = \sum_{p=-m}^{m} \sum_{q=-n}^{n} h(p,q)g(i-p,j-q) \tag{2}$$

$$h(p,q) = \frac{1}{(2m+1)(2n+1)} \tag{3}$$

Median filtering is often preferred over mean filtering because it removes noise without blurring the image [10]. A median filter replaces the gray level with the median gray level in the neighborhood $(2m + 1) \times (2n + 1)$. Note that noise reduction may take place at any point in the preprocessing steps, and is sometimes used subsequent to edge detection [8].

Illumination

Another issue with microscopy images involves uneven illumination. A common assumption is that uneven illumination can be treated as a low frequency signal added to the image. A low pass filter can then be used to correct the problem. Typical filters used include linear smoothing Gaussian filters [11] and low-pass filters (which might require repeated application) [12].

Image Simplification

Thresholding is a common form of image simplification. Threshold gray-level intensity is chosen, and every pixel above that value is turned white while the remaining background pixels are turned to black [7]. This is shown in Eq. (4) below, where T represents the threshold value.

$$g(i,j) = \left\langle \begin{matrix} g(i,j) > T, 1 \\ g(i,j) \le T, 0 \end{matrix} \right. \tag{4}$$

Selection of a correct threshold value is critical. Perregrina-Barreto et al. generated an image histogram and used the second most frequent gray level as the threshold [9, 13]. Threshold levels are not always used, however. Chatterjee et al. converted a gray-scale image of a dual phase steel into a binary image as the first step in classifying pixels into one of three categories [14].

Typical Pre-processing Algorithms

Various algorithms for pre-processing metallurgical images exist. Latala and Wojnar used this algorithm for analysis of austenitic stainless steel: shade correction followed median filtering (both as a form of background noise removal), thresholding to obtain a binary image of grains, and finally edge closing [7]. For AISI 1008 steel, Peregrina-Barreto *et al.* used the following methodology: convert the image to gray scale, simplification of the image by reducing the variation in gray scale using a median filter, establish a threshold value to differentiate between the grains and the boundaries by taking the highest occurrence level before the peak of the image after median filtering, and eliminating noise [9].

For a two-phase titanium alloy at the scanning electron microscope level, Chraponski and Szkliniarz used a median filter for smoothing, color separation, histogram normalization, gradient edge detection, another histogram normalization, followed by thresholding [8].

Edge Detection

The objective of preprocessing is to prepare an image for feature detection. In metallography, features may be grain boundaries, inclusions, or material phases. This research focuses on edge detection used to detect grain boundaries, or identify other characteristics such as inclusions, cracks, discontinuities, etc.

A digital edge can be defined as a boundary between two regions of different brightness. Edge detection is the process of examining a digital image to determine where edges are present, and focuses on calculating the first or second-order derivatives of the image function *g(x,y)*. Operators or masks can be applied to neighborhoods in a digital image to calculate the digital gradient [10]. Typical operators used include Sobel, Roberts, and Prewitt [7]. A Robert's mask would be expressed as shown in Eq. (5).

$$\hat{g}\,(i,j) = abs[g(i,j) - g(i+1,j+1)] \tag{5}$$

The gradient operator for a digital image, based on finite differences rather than derivatives, is summarized Eq. (6) [10].

$$\begin{aligned} \hat{g}\,(i,j) &= \left[\Delta_x{}^2 + \Delta_y{}^2\right]^{\frac{1}{2}} \\ \Delta_x &= g(i,j) - g(i,j-1) \\ \Delta_y &= g(i,j) - g(i-1,j) \end{aligned} \tag{6}$$

After edge detection, the edge detected image may be converted to a binary format to more clearly differentiate between grain boundaries and grain interiors. Similar to thresholding, binarization will result in an image that is black and white rather than grayscale.

Implementation Using Mathematica

Images can be imported into Mathematica using a variety of approaches, with the most intuitive being importing an image file and the simplest being copy and paste.

The first operation applied to an image is conversion to grayscale using the ColorConvert function to convert the image to colorspace "Grayscale." This converts the pixel data to a single number between 0 and 1 representing the gray intensity level. Histograms for all images are easily generated using the ImageHistogram command, where the only argument required is the image [15].

Mathematica supplies numerous filters for image processing. Some of the most commonly used include the Gaussian, Laplacian, Gauss Laplacian, mean, and median filters.

The GaussianFilter command filters the image by convolving it with a Guassian kernel with a pixel radius of *r;* the LaplacianGaussianFilter will convolve the image with a Laplacian-of-Gaussian kernel, also of pixel radius *r* [16]. However, the GaussianFilter command will also allow you to specify separate radii for the x and y directions.

The mean and median filters are applied to an image using MeanFilter and MedianFilter, respectively. They both require a neighborhood size *r* as an input argument. The pixel is replaced by the mean (or median) based on a neighborhood of $(2r + 1) \times (2r + 1)$ [16].

Thresholding is implemented using the ColorQuantize which takes as arguments the image to perform the operation on and the number of colors (or grayscale values) to use in representing the image. If the image needs to be represented in only black and white, the Binarize command is used.

Results

The Mathematica scripts developed were used to analyze a cast aluminum sample and a carbon steel sample, both obtained from Buehler. The metallurgical microscope was a Nikon type 104 with a Nikon Japan 50×/0.80 lens. The digital image were captured using ZView Measurement and Imaging Solutions DMP 1000, version 3.74. The magnification level used was for both samples 50×. A 500 × 500 pixel region was selected from each image for use in the scripts discussed.

Two scripts are presented in this paper. The first allows the user to examine side-by-side the effect of various filters (including both the resulting image and the histogram). The second presents the effects of edge detection and thresholding side-by-side. Copies of both scripts can be obtained from the author upon request.

Filtering

First, the image is converted to grayscale and the pixel intensities rescaled from 0 to 1. Next, six different commonly used filters were applied individually: mean, median, Wiener, Laplacian Gaussian, gradient, and Gaussian. Each filtered image was also rescaled for the pixel ranges to lie along 0–1 using ImageApply.

Figure 1 shows the module being used on a cast aluminum specimen, while Fig. 2 shows the same module as used on a carbon steel specimen.

Different neighborhood sizes were used with the filters to attempt to get the best image. This script is fully interactive, allowing changes to the neighborhood size to be reflected instantly. It also allows for a side-by-side comparison of filtering results, to allow an inexperienced user to choose the best type of filter and neighborhood size for their application. It also clearly shows the effect that each type of filter has on the histogram of the image.

Figure 3 contains the Mathematica script used for thism module. For the user to change the image, it merely requires one simple modification to the code: pasting a different image into the script.

Edge Detection

Figure 3 shows the edge detection and thresholding module. In this example, the processed were applied to the median filtered cast aluminum image from Fig. 1.

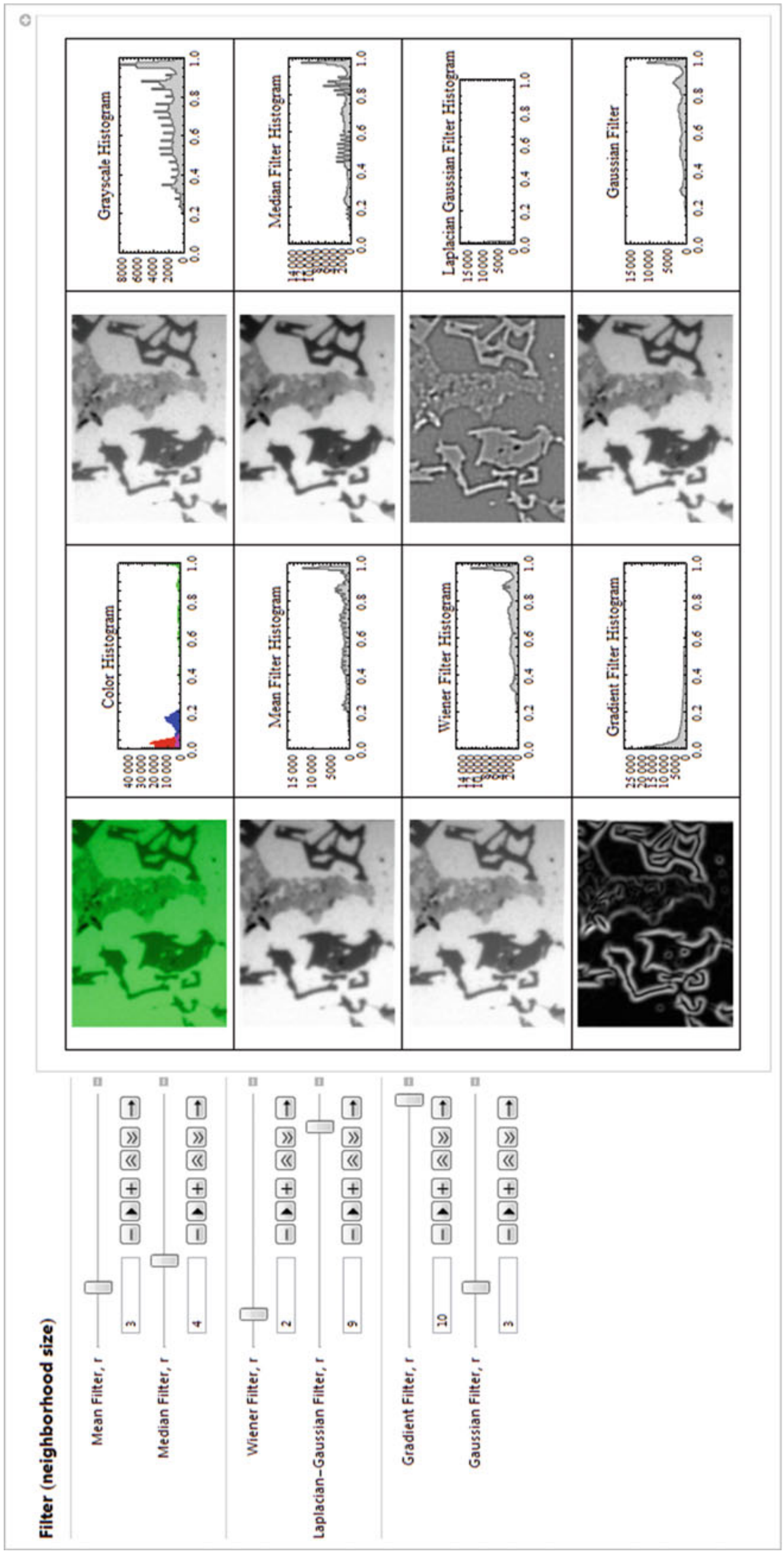


Fig. 1 Filtering module applied to a cast aluminum sample image

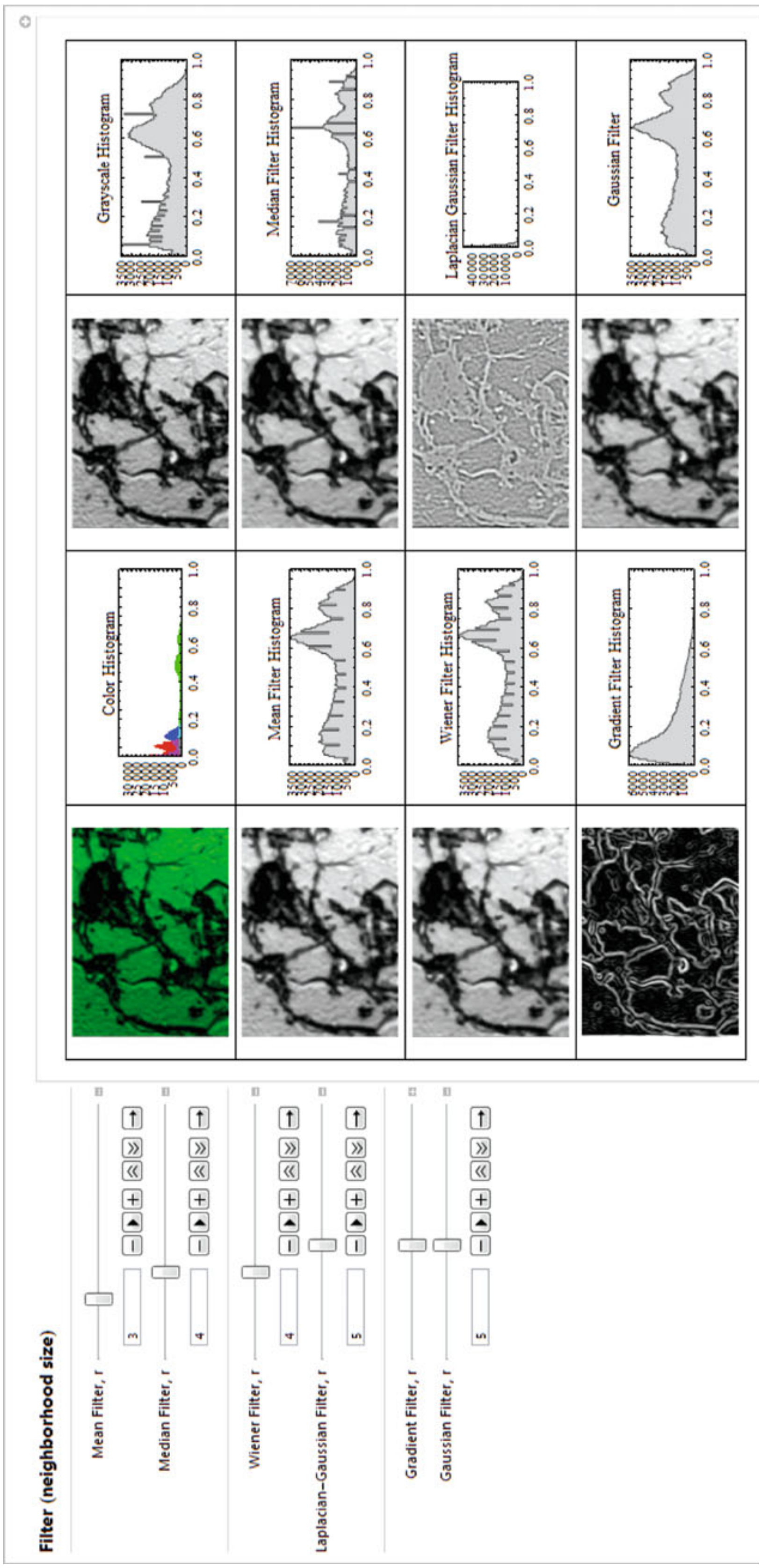
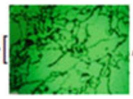


Fig. 2 Filtering module applied to the carbon steel sample



```
Manipulate[a = ImageCrop[ [image] , 500, Right];
 ah = agh = ImageHistogram[a, PlotLabel → "Color Histogram", FrameTicks → True]; ag = ColorConvert[a, "Grayscale"] // ImageAdjust;
 agh = ImageHistogram[ag, PlotLabel → "Grayscale Histogram", FrameTicks → True]; agm = MedianFilter[ag, rm] // ImageAdjust;
 agmh = ImageHistogram[agm, PlotLabel → "Median Filter Histogram", FrameTicks → True]; agm2 = MeanFilter[ag, rm2] // ImageAdjust;
 agmh2 = ImageHistogram[agm2, PlotLabel → "Mean Filter Histogram", FrameTicks → True]; agw = WienerFilter[ag, rw] // ImageAdjust;
 agwh = ImageHistogram[agw, PlotLabel → "Wiener Filter Histogram", FrameTicks → True]; agli = LaplacianGaussianFilter[ag, lg] // ImageAdjust;
 aglh = ImageHistogram[LaplacianGaussianFilter[agli, lg], FrameTicks → True, PlotLabel → "Laplacian Gaussian Filter Histogram"];
 g = GradientFilter[ag, gn] // ImageAdjust; g1 = ImageHistogram[g, FrameTicks → True, PlotLabel → "Gradient Filter Histogram"];
 t = GaussianFilter[ag, ga] // ImageAdjust; t1 = ImageHistogram[t, PlotLabel → "Gaussian Filter", FrameTicks → True];
 GraphicsGrid[{ {a, ah, ag, agh}, {agm2, agmh2, agm, agmh}, {agw, agwh, agli, aglh}, {g, g1, t, t1}}, ImageSize → {800, 550}, Frame → All],

 (* Controls *)
 Delimiter, Style["Filter (neighborhood size)", 14, Bold], Delimiter, {{rm2, 4, "Mean Filter, r"}, 1, 10, 1},
 {{rm, 4, "Median Filter, r"}, 1, 10, 1}, Delimiter,
 {{rw, 9, "Wiener Filter, r"}, 1, 10, 1}, {{lg, 5, "Laplacian-Gaussian Filter, r"}, 1, 10, 1}, Delimiter, {{gn, 5, "Gradient Filter, r"}, 1, 10, 1},
 {{ga, 5, "Gaussian Filter, r"}, 1, 10, 1}, ControlPlacement → Left, TrackedSymbols :→ Automatic]
```

Fig. 3 Mathematica script for filtering module

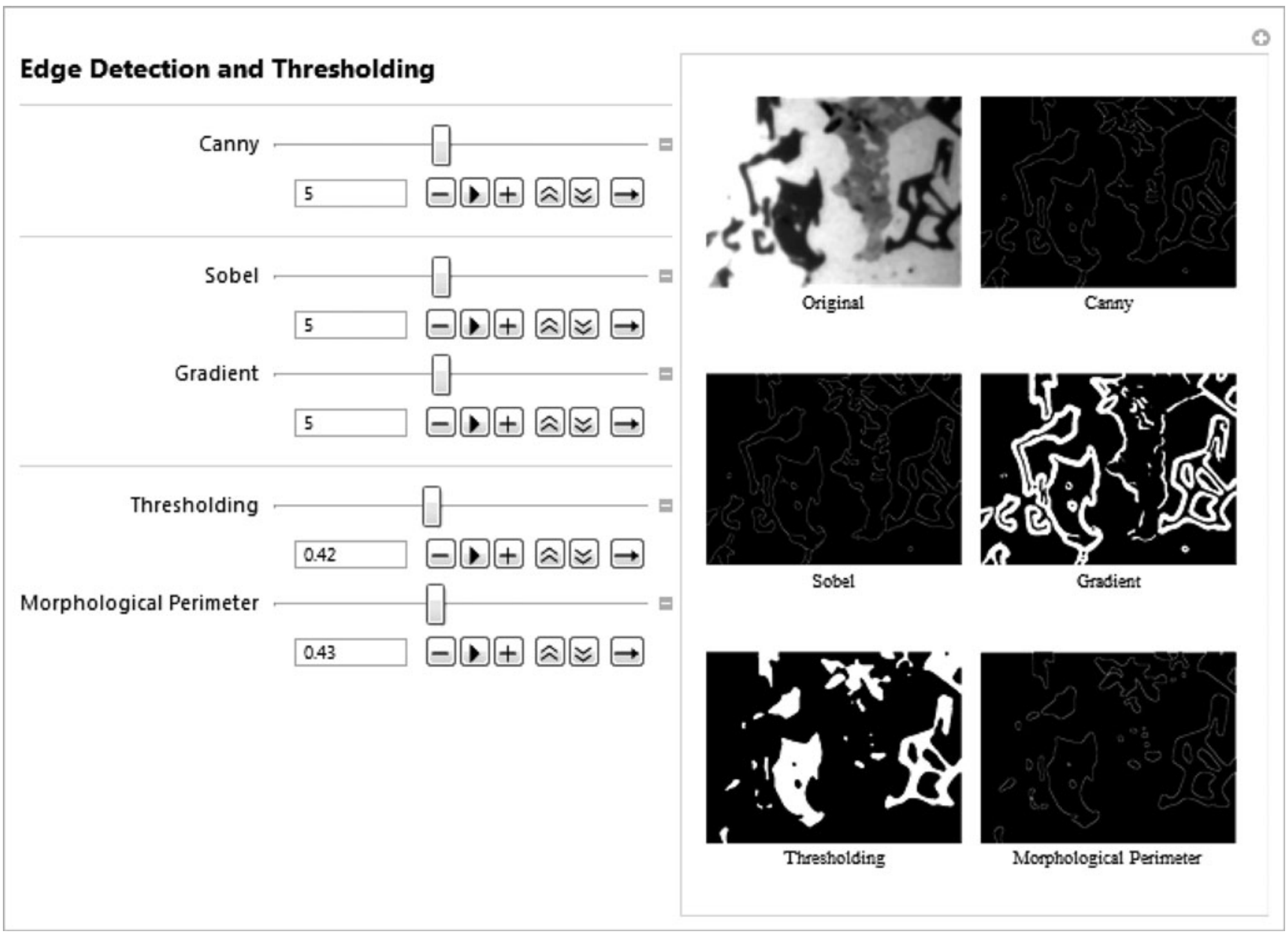


Fig. 4 Edge detection and thresholding applied to cast aluminum sample

Three edge detection methods were used: Canny, Sobel, and Gradient. In order to more clearly see the results of the Gradient edge detected image it was binarized so that white pixels represented the edges. The neighborhood values used can be seen in Fig. 2.

In addition, thresholding was applied to the image using the ContourDetect command in Mathematica. Any pixels with a value greater than 0.42 were turned white, with all other pixels set to black. This allows us to see the darker colored grains separate from the other grains.

The morphological perimeter command works in a similar fashion, with perimeters only showing for areas with a pixel threshold greater than 0.43 (Fig. 4).

Conclusions

The objective of this paper was to present two Mathematica scripts developed as image processing modules for use by beginners in the area of digital metallography. Both scripts made use of the Manipulate command to allow the user to interactively make changes to filter, edge detection, and thresholding parameters in order to achieve the best possible pre-processed image for their use.

By allow the user to see the various filters and edge detection results side by side with the original image, the scripts serve as learning tools for obtaining a deeper understanding of the relationship between the parameters involved in image processing and the differences between commonly used algorithms.

Finally, the scripts presented can be used for other applications requiring filtering and edge detection, as well.

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Using Mathematica to Accurately Approximate the Percent Area of Grains and Phases in Digital Metallographic Images

Adarsh Kesireddy and Sara McCaslin

Abstract
The objective of this paper is to present an effective methodology to find out the cumulative percentage area of grains and phases present in a digitally captured metallographic image using image processing commands available in Mathematica 8.

Keywords
Image processing • Metallography • Mathematica • Digital image processing • Grain area

Introduction

The term "image processing" refers to process of transforming one image into another image. This broad field can include image correction, filtering, feature detection, and more. Its areas of application are also vast, ranging in scale from the processing of satellite imagery down to scanning electron microscope images.

In this paper, the image processing focus is on processing digital images of prepared metal specimens as viewed under a metallurgical microscope. The goal of image processing in this research is to determine the percent areas of different types of grains or materials evident in a digital metallographic image.

Background

Various procedures to achieve the goal of image processing in metallography have been implemented through the years. For edge detection and area approximation of grains in austenitic stainless steel, Latala and Wojnar used shade correction, median filtering, binarization, and edge closing [1]. A similar process was used to analyze micrographs of sintered steel: conversion to gray-scale, filtering to remove noise and scratches, and then binarization [2].

Marmo et al. also used binarization to differentiate between textures in carbonate rocks [3]. For AISI 1008 steel, Peregrina-Barreto et al. used gray-scale conversion, median filtering, thresholding to determine grain boundaries and edges, and filtering for noise elimination [4].

It is important to note, however, that statistical methods are also implemented to quantize the grain structures as evidenced by a recent paper by Kose et al. [5].

Image Processing

Pre-processing

The goal of pre-processing metallurgical images is to prepare the image for extraction of useful information or data. Grayscale conversion and filtering are the most common pre-processing steps in metallurgical image processing.

The first step in pre-processing a digital metallographic image is typically to convert it to gray scale instead of color. When converted to gray scale, each pixel is represented by one number indicating grayscale intensity. This reduces the amount of data that must be processed for the image, which in turn reduces the complexity of all remaining operations performed on the image.

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_49,

When an image is captured by camera; variations in intensity of light, variations in illusion or variations in contrast might occur, which would in turn lead to errors in image. In addition, the concave nature of the lens also might cause an error in image. In order to process an image to find out the particulars from it, errors must be removed. Filters come into play for removal of these errors [6]. Filters also allow small details and edges to be enhanced [7].

When filtering noise from images, the assumption is that any single pixel in an image is much smaller than the details of interest. This implies that neighboring pixels most likely belong to the same phase. Various methods have been used to eliminate noise, including median filters [1, 8] and modified mean filters [4]. Note that median filtering is preferred over mean filtering because it does not blur the image [7].

Uneven illumination can adversely affect an image. It is typically treated as a low frequency signal that has been added to the image, and a low pass filter can be used to correct the problem. Linear smoothing Gaussian filters [9] can also be used in addition to low-pass filters [10].

Thresholding allows the different phases in a material to be revealed. The simplest form of thresholding is binarization, where every pixel is either changed into black or white, based on its gray-level intensity. Chatterjee et al. converted a gray-scale image of a dual phase steel into a binary image as the first step in classifying pixels into one of three categories [11].

Image quantization is another form of thresholding that reduced the number of gray-scale intensity values in an image. It works well to reveal three or more phases present in a metallurgical image.

Processing

Once the image has been filtered and either binarized or quantized, the pixels can be counted using specially developed code for the application or through a histogram. Percentage area of phases in an image can then be easily approximated. This approach eliminates the need for calibration of the microscope or prior knowledge of the dimensions of a pixel in the image, but can be easily expanded to approximate the area of various phases in an image.

Procedure and Implementation

Recall that the objective of preprocessing is to prepare an image for feature detection. In metallography, features may be grain boundaries, inclusions, or material phases. In this paper, the feature detection focuses on determining the percentage of different grain structures present. This section describes the software tools and procedure. Mathematica was chosen because of its image processing capabilities [12, 13].

Table 1 Image processing filters available in Mathematica 8

Linear filters	Non linear filters
Blur	Median
Sharpen	Min
Gaussian	Max
Gradient	Commonest
Laplacian Gaussian	Range
Laplacian	Entropy
Mean	Standard deviation
Wiener	Harmonic mean
Image convolve	Geometric mean
Image correlate	Kuwahara
Derivative	Bilateral
Non local filters	Mean shift
Image deconvolve	Perona Malik
Total variation	Curvature flow

The first step is to import the image into the Mathematica environment. This can be accomplished through copy and paste or directly importing an image from a file.

The first operation applied to the image is the ColorConvert function to convert the image to colorspace "Grayscale" [14]. This converts the pixel data to a real number between 0 and 1 representing the gray intensity level, where 0 would be black and 1 would be white.

A histogram of the grayscale image is then generated. Histograms for any image, whether color or gray scale, images are easily generated using the ImageHistogram command [14].

A key phase of this research was to determine what types of filters are best adapted for binarization or image quantization. Mathematica supplies numerous filters for image processing. These are listed in Table 1. Each filter listed in Table 1 was applied to the gray scale image. A neighborhood size of 1 was used to allow for consistent comparison between filters.

After filtering, each image was either binarized or quantized. ColorQuantize requires an argument indicating the number of colors (or grayscale values) to use in representing the image and Binarize reduces the image to black and white [15]. For example, if there are three distinct phases present in the image then the image should be quantized to three grayscale levels. If the area comparison only needs to focus on major grains versus minor grains, binarization of the image into black and white is sufficient.

To approximate the percentage of various phases or grains, histogram or pixel count data can be used. The number of pixels in each gray scale level are counted and a percentage of the whole is then calculated.

Results

The procedure was applied to a sample of cast aluminum and a sample of tool steel, both prepared by Buehler as high quality metallurgical specimens. These were used so that filter comparisons could be performed using the highest quality samples possible. The metallurgical microscope used to capture the images was a Nikon type 104 with a Nikon 50×/0.80 lens. The digital image were captured using ZView Measurement and Imaging Solutions DMP 1000, version 3.74 running on Windows XP. All digitally captured images were saved as jpeg files and inserted into the Mathematica script.

Results for Filtering

Table 2 lists the filters found to be the best for subsequent binarization, while Table 3 lists the filters best adapted for images requiring three or more gray scale levels. Comparing filters is based on how cleanly the differentiate between various phases and grains.

Note that the gradient and range filters are more adapted to isolating edges of grains rather than the area of grains. In this research, edge detection was not considered.

Figure 1 shows the original grayscale tool steel and cast aluminum images used. The images were both 500 × 500 pixels taken from a much larger image taken at ×50 magnification.

Figure 2 shows a representative (not exhaustive) comparison of results for the tool steel and cast aluminum samples, all using a neighborhood size of 1 and exported in graphics interchange format. For binarization, note that the blurred filter eliminated the smaller details and provided the smoothest edges. The range filters served more to emphasize edges, which was not the focus of this research, and entropy filters were not beneficial.

Figure 3 also shows representative results focusing on the cast aluminum sample. These images were all filtered and reduced to three gray-scale levels. Note again that the range filter emphasizes grain edges. Image correlate used a Gaussian kernel of radius 1 for correlation.

Results for Area Approximation

For the area approximation results, the aluminum specimen was chosen because it clearly has three different types of phases present. Using the same images as shown in

Table 2 Filters best adapted to subsequent binarization

Linear filters	Non linear filters
Blur	Median
Sharpen	Min
Mean	Max
Wiener	Commonest
Image convolve	Harmonic mean
Image correlate	Geometric mean
Gaussian	Kuwahara
	Bilateral
	Mean shift
	Peronal Malik
	Curvature flow

Table 3 Filters adapted to subsequent quantization

Linear filter	Non linear filter
Blur	Median
Sharpen	Min
Mean	Max
Wiener	Commonest
Image convolve	Harmonic mean
	Geometric mean
	Kuwahara
	Bilateral
	Mean shift
	Peronal Malik
	Curvature flow

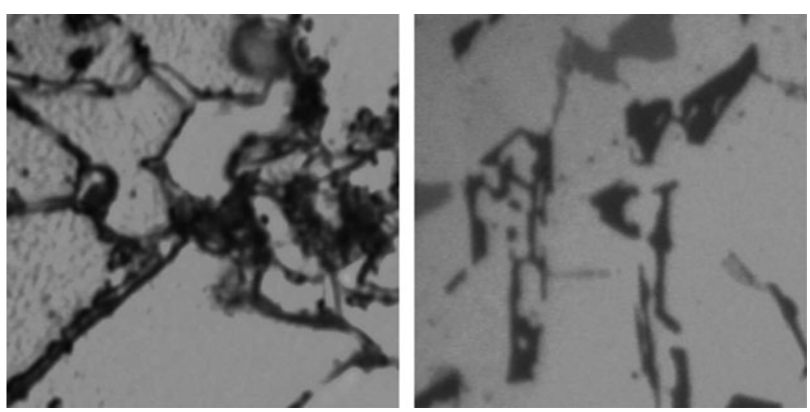

Fig. 1 Grayscale representations of tool steel and cast aluminum images

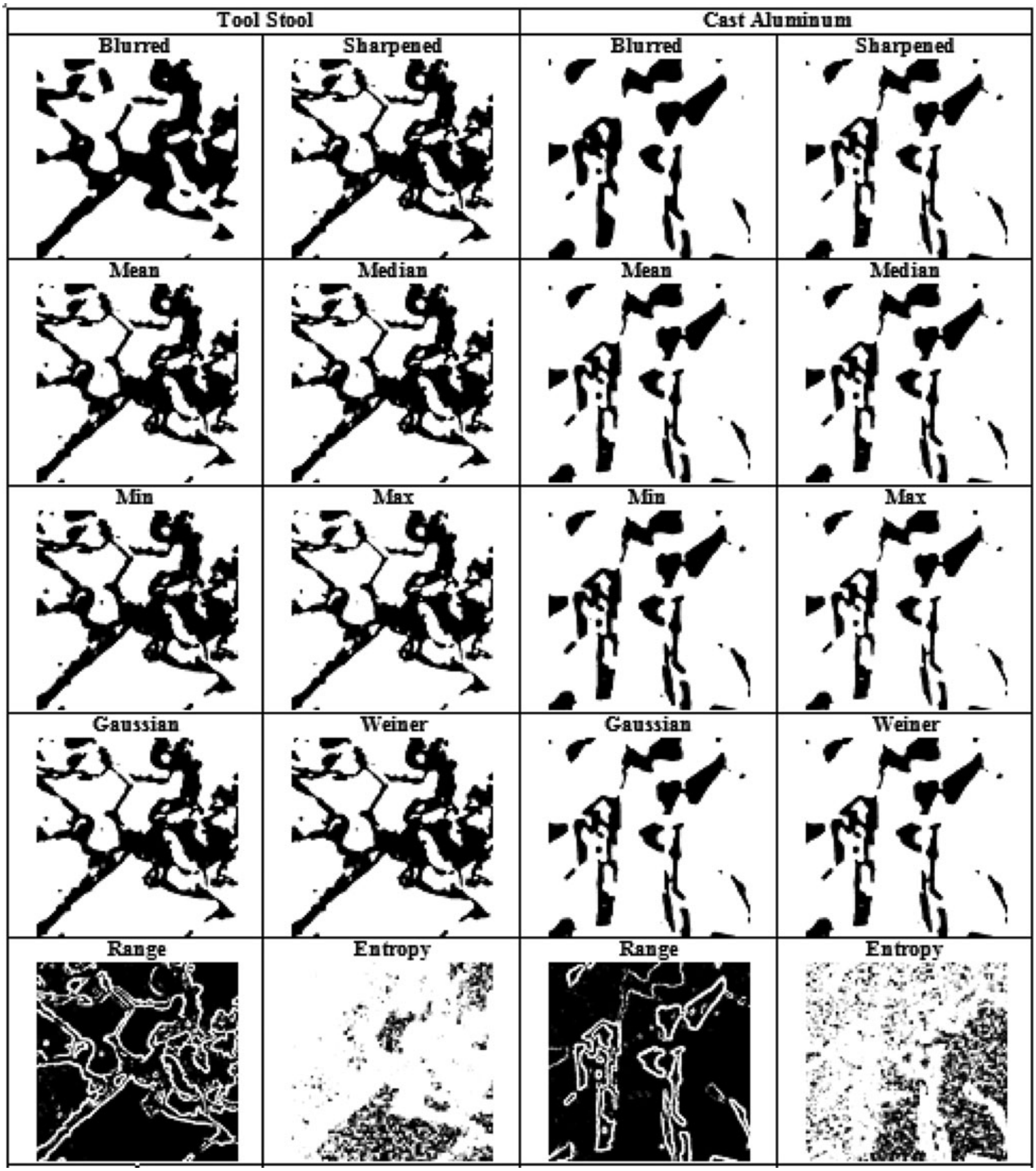

Fig. 2 Filter comparisons for binarized images, with tool steel on the *left* and cast aluminum on the *right*

Fig. 2 for the correlate, Weiner, sharpen, blur, median and mean filters, a pixel count was performed.

Figure 4 shows a histogram comparison of the aforementioned filters applied to the aluminum image after the image has been filtered and quantized to three shades of gray. For convenience, the gray levels have been named light, medium, and dark. These results correspond well to visual inspection of the cast aluminum images which have a light color dominating.

Table 4 shows the calculated percentage areas based on the pixel count results illustrated in Fig. 4.

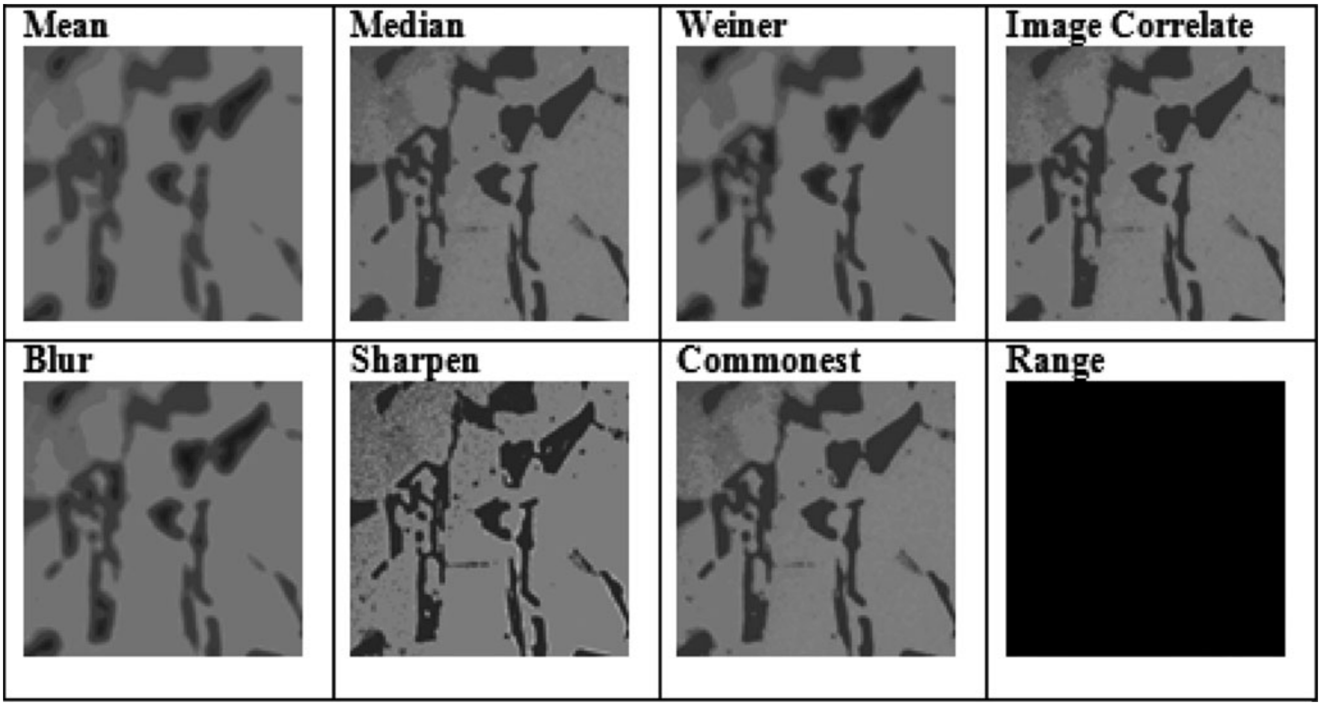

Fig. 3 Filter comparisons for cast aluminum images reduced to three levels of gray

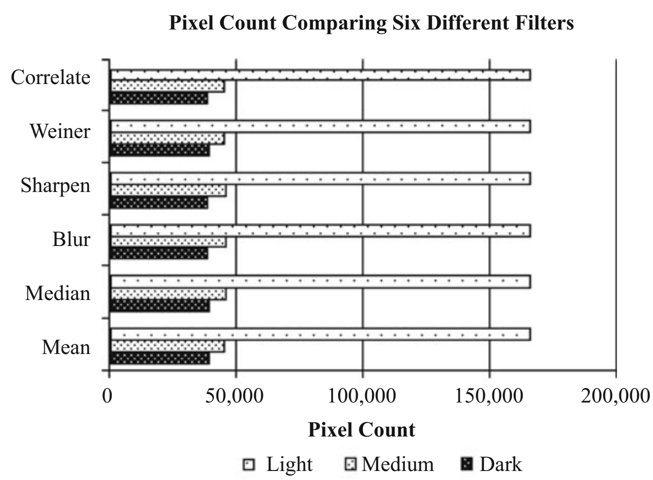

Fig. 4 Pixel count comparisons for six different filters applied to a cast aluminum image quantized to three shades of gray

Table 4 Percentage areas using six different filters

	Dark	Medium	Light
Mean	15 %	18 %	66 %
Median	15 %	18 %	66 %
Blur	15 %	18 %	66 %
Sharpen	15 %	18 %	66 %
Weiner	15 %	18 %	66 %
Correlate	15 %	18 %	66 %

Note that all six filters gave identical results, even though the histograms indicated some difference in the pixel count. This can be attributed to the massive number of pixels even in a small image such as the one used. An image with 500 $\times$ 500 pixels has 250,000 pixels. For larger images, the differences would be even more imperceptible.

Conclusions

The objective of this paper was to use Mathematica tools to approximate the percent areas of different regions of interest in a digital metallographic image. Using tool steel and cast aluminum as test images, various Mathematica filters were applied to grayscale versions of the test images to determine which filters would be appropriate for quantization. Filters such as Gaussian and derivative filters were found better suited for edge detection while mean, median, and sharpen filters were found to work well to clearly define grain areas and phases.

After appropriate filters were determined, six types of filters were used on the cast aluminum after it was reduced to three grayscale levels. The percent area of three regions of interest were calculated using the filtered images. Of the six filters, all gave identical results for percent area light, medium, and dark. If the microscope has been calibrated and pixel dimensions are known, then the actual area in mm^2 can easily be determined once the pixel count is known.

Based on the results shown in Table 4, it may be concluded that if a filter provides clearly defined areas of interest, the actual choice of filter has minimal impact on the final percentages. Larger images could then be processed more efficiently by using a more simple filter with minimal impact on the results. Further research may show that the neighborhood size used for the filter has more impact on the pixel area than the type of filter used.

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Real-Time Indexing of Complex Data Streams

Petr Chmelar, Michal Drozd, Michal Sebek, and Jaroslav Zendulka

Abstract
The paper deals with indexing of a complex type data stream stored in a database. We present a novel indexing schema and framework referred to as ReTIn (Real-Time Indexing), the objective of which is to allow indexing of complex data arriving as a stream to a database with respect to soft real-time constraints met with some level of confidence for the maximum duration of insert and select operations. The idea of ReTIn is a combination of a sequential access to the most recent data and an index-based access to less recent data stored in the database. The collection of statistics makes balancing of indexed and unindexed parts of the database efficient. We have implemented ReTIn using PostgreSQL DBMS and its GIN index. Experimental results presented in the paper demonstrate some properties and advantages of our approach.

Keywords
Real-Time • Indexing • Complex data • Streams • Database

Introduction

During last three decades data stream sources and data-intensive applications has appeared [1]. In contrast to traditional databases where data is stored in finite data sets, a data stream is a continuous, possibly infinite stream of changing and often high dimensional data that must be processed under some real-time constrains usually. Examples of such applications include network monitoring, financial and security, surveillance, sensor networks and other applications processing temporal data. Although research in real-time database systems received a lot of attention in last two decades, the primary objective of the real-time support in these databases was different compared to data streams [2]. Several basic data stream specific techniques have been developed for continuous querying [3], sliding window query processing [4], approximate query processing [5], sampling, sketching and synopsis construction [6]. Most of these techniques rely on data stream processing in the main memory, however this might be unsatisfactory for applications mentioned.

The goal is to store the data in a database. An index is a data structure designed to increase the data access speed at the expense of decrease the data modification speed. B-tree, hashed or bitmap are not appropriate for high-dimensional data. In addition, costs of updates limit their effective use. The problem of index maintenance is more critical when employed advanced indexing techniques for high-dimensional data as KD-tree, R-tree or inverted index. In such a case, it may be necessary to rebuild the index completely after some time. As a result, some data stream specific indexing methods have been developed. Multi-granularity aggregation indexing [7] is an integrated structure managing summarized information of snapshots. Po-tree [8] is an indexing structure for spatio-temporal databases with soft real time constraints which combines two different structures for spatial and temporal dimensions. However, we haven't found a general approach that satisfies our needs.

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_50,

Our research in real-time and data stream indexing was motivated by two areas. First is the need to index metadata of moving objects produced by computer vision modules of our experimental surveillance network system SUNAR [9]. The main operation of SUNAR is the persistent tracking of objects moving in a space watched by multiple surveillance cameras. The tracking is based on similarity of values of moving objects characteristics, both spatio-temporal and visual. The intelligent cameras produce a data stream of this kind, which is necessary to index to make the similarity search possible in near real-time. The second domain that has motivated our research is computer security, namely a data stream processed by an intelligent intrusion detection system (IDPS) that monitors and analyzes the computer network traffic in real time. It is based on extended data flow protocol, which includes source and destination IP addresses, timing, packet sizes and signatures of both packets and attacks or another data that must be logged, analyzed and reported as soon as possible.

There are many other application domains that deal with streams of spatio-temporal data representing moving objects. For example, an air-traffic control to support decisions about flight paths and the landing order based on data such as position, altitude, speed or fuel left. There is rarely enough time to re-index the database under special circumstances—as in a geo-graphic information system presented in a case study [8] that stores and evaluates data issued from an array of spatially referenced sensors, used to a natural disaster prevention.

In this paper we present an indexing schema and framework referred to as ReTIn (Real-Time INdexing), the objective of which is to allow indexing of complex data arriving as a stream to a database with respect to soft real-time constraints. A concept of a soft real-time constraint is similar to one known from real-time databases [10]. It is not a hard constraint that has to be always met but the number of its violations must be minimized. The idea of our approach is similar to a real-time index/cache consistency maintenance technique Codir for text retrieval systems presented in [11]. It builds a transient index for new document updates and queries are processed using both permanent and transient index. To minimize performance overhead associated with document database updates, Codir integrates transient index with permanent index lazily using piggybacking [12] for statistics.

Our indexing schema consists of two main parts where data is stored. Values arriving in a data stream are inserted into the unindexed part that contains the most recent data. Less recent data is stored in the other part which is indexed on backgroud. Queries are processed accessing data in both parts. The schema maintenance, which includes moving data from unindexed part to indexed one, is controlled by two soft real-time constraints for query and insert processing and it uses piggybacking to collect and update statistics. The schema maintenance runs as a background process for all database operations.

The content of the paper is organized as follows. The next section contains problem formulation and describes the structure of the proposed indexing schema and operations on it. Section "Experimental Results" presents experimental results and section "Conclusions" concludes the work.

ReTIn Indexing Schema Concepts

The ReTIn indexing schema supports the most important real-time data stream operations on a single table in the database, in which a portion of the stream is stored—insert and select (executes a query). There are three parameters that control the behavior of the indexing schema: a maximum time of insert operation $T_{I\ MAX}$, a maximum time of select operation $T_{S\ MAX}$ and a confidence factor R. Then the schema meets the constraints $T_{I\ MAX}$, and $T_{S\ MAX}$ as soft constraints with confidence R*σ where σ is a standard deviation of execution times distribution and R a selected confidence factor as described further.

Problem Formulation

Let *ds* be a data stream of data elements *e* of a type *dt,* which is complex in general—composite and/or multiple-valued. The data stream is processed using a sliding window. Assume that the window is larger than it fits in the main memory. The content of the window is stored in a database table D, not necessarily normalized. The size of the window is not specified in advance. Instead, real-time constraints $T_{I\ MAX}$ and $T_{S\ MAX}$ are (user) specified durations of insert and select operations on the table D. Thus, the size of the window is dependent on the duration of these operations. It is required to minimize the number of violations of the timing constraints. The softness of the constraints is dependent on the probability of their violation. We can introduce estimates for maximum processing times of insert and select operations (estimated maximum) on D: M[T_I] and M[T_S], respectively:

$$M[T_O] = \mu(T_O) + R * \sigma(T_O) \tag{1}$$

where OPERATION is either INSERT or SELECT. The estimates are derived from the expected duration of the operation E[T_O]. It is given by the average processing time of the operation μ(T_O), and its standard deviation σ(T_O). The real value R is a confidence factor which determines together with the standard deviation σ the confidence interval or the allowable probability of the constraint violation. For example, provided Gaussian normal distribution the value $R = 3.0$ results in 99.73 % probability of not exceeding the $T_{O\ MAX}$. Data modification operations are usually not defined on streams.

Proposed Solution

The table *D* consists of two subtables, namely *D0* and *DI* that differ in access methods. Data in *D0* is accessed by means of full scan whereas data in *DI* is indexed. All incoming data of the data stream *ds* is inserted into *D0*. *DI* contains less recent data of the stream that were moved there from *D0* during indexing schema maintenance operations in the past. The objective of the schema maintenance operation is to improve performance to meet the soft constraints $T_{I\ MAX}$ and $T_{S\ MAX}$. There are two cases that result in accomplishing the schema maintenance operation:

1) Duration of insert or select operation that is to be executed would violate $T_{I\ MAX}$ or $T_{S\ MAX}$ with high probability,
2) full scan of *D0* takes more time than access to data in *DI*.

To be able to check for these situations, some temporal statistics must be gathered during the execution of operations on ReTIn. In 1) reduction of the *DI* part may be necessary. It is done by moving the less resent data, which is considered to be obsolete to some overflow storage, or by deleting it. This data will not further be available under ReTIn constraints, but may stay in the database. The schema maintenance operation should not block and significantly delay insertion of new stream data and querying the data in *D*. We solve it such a way that the maintenance operation is performed asynchronously as a background process to insert and select operations. In addition, the maintenance operation must be atomic.

Our approach is advantageous in at least two situations. First, when the duration of a sequential scan for a select operation on *D* would take much longer than a corresponding index scanor when it would violate the constraint $T_{S\ MAX}$. Second, when updating an index would take much longer than a simple insertion of data or it would violate the constraint $T_{I\ MAX}$:

$$\begin{aligned} &E[T_{SD0}] \gg E[T_{SDI}], E[T_S] > E[T_{SMAX}] \\ &E[T_{UI}] \gg E[T_I], E[T_{UI}] > E[T_I MAX] \end{aligned} \qquad (2)$$

where E[*TO*] stands for expected duration of a corresponding operation and *TUI* stands for index update time.

ReTIn Schema

The basic elements of the ReTIn indexing schema are shown in Fig. 1. It consists of the hierarchy of three tables. All the tables have the same schema (*t*: timestamp, *d*: *dt*), where timestamp is an underlying DBMSs data type and *dt* is the type of an element of the data stream *ds*. Because the data type *dt* can be a composite and/or multiple-valued, the column *d* can contain arrays, subtypes or nested collections.

D is a virtual table that encapsulates tables *D0* and *DI*. All clients' insert and select operations run on it (encapsulation).

D0 is a base table containing the recent data of the data stream *ds* that has been inserted into *D*. The data is accessed by a full scan.

DI is a virtual table that encapsulates one or more base tables P*i* ($i = 1, \ldots k$) referred to as partitions. The number of partitions *k* changes in time. There are one or more indexes on *DI* or each P*i* .

MD is a base table that contains temporal statistics concerning the insert and select operations on tables *D*, *D0* and *DI*, as illustrated in Fig. 1. It will be described in more details in the following section.

Operations of ReTIn

The ReTIn indexing schema provides two logical operations to its clients (operations of the DBMS):

1. INSERT INTO *D*(*d*) VALUES(*e*)—inserts an element *e* into table *D*,
2. SELECT *statement*—selects data from D.

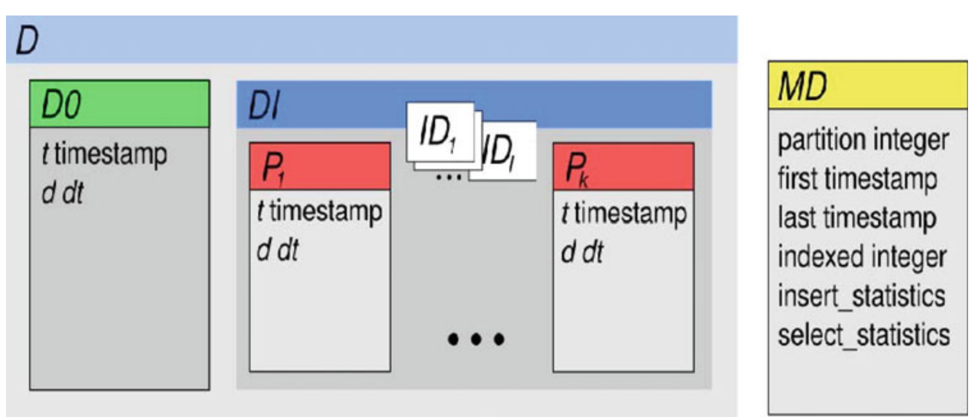

Fig. 1 Basic elements of the ReTIn indexing schema. The table *D* encapsulates subtables *D0*, which is not indexed, and indexed one *DI*. *DI* consists of partitions P*i*. Metadata related to all partitions P*i* and *D0* are stored in the *MD* table

INSERT and SELECT statements are conforming the SQL standard and they fully rely on corresponding operations of the underlying DBMS (no special operations needed). The only additional activities include logging of queries and the update of temporal statistics used for the decision whether the indexing schema maintenance operation should be performed. It is an internal operation of the ReTIn role, which changes the content of tables *D0* and *DI* in such a way that the soft constraints *TI MAX* and *TS MAX* will be met for some period of time. The maintenance is performed asynchronously to all operations.

All operations are described more formally below. Inputs, outputs (data only is considered here) and preconditions used are specified. Algorithms are described in a pseudocode.

Algorithm 1 Operation INSERT

```
Input: e – a data stream element
Output:
Precondition: INSERT INTO D(d) VALUES(e) performed
INSERT INTO D0 VALUES (current timestamp, e);
update_insert_statistics();
SIGNAL "check RT constraints";
```

Algorithm 1 presents the INSERT operation. It is ensured, that the new value will always be inserted into the table *D0* without the need to update any index. The database must support (instead) triggers. We use also table inheritance (since SQL: 1999) for partitioning. The operation update_insert_statistics() updates statistics related to the insert operation. These statistics are stored in the metadata table *MD*. The operation updates sums that are necessary to compute the mean $\mu(TI)$ and the standard deviation $\sigma(TI)$. The statement SIGNAL represents the sending of an asynchronous message to the process responsible for the indexing schema maintenance operation. For example dbms_alert in Oracle or listen/notify concept in PostgreSQL. If the DBMS does not support this functionality, it is necessary to set a sleep period for the maintenance process, the delay can be derived from the frequency of insertions.

Algorithm 2 Operation SELECT

```
Input: a select statement
Output: rs – a result set, retrieves data from D
Precondition: SELECT d FROM D … query performed
rs = EXECUTE SELECT statement;
update_query_statistics(statement);
```

Algorithm 2 presents the SELECT operation. Its execution is optimized by DBMS's query processing planner and optimizer. We suppose the optimizer uses indexes on the table *DI* (P_i) and a full scan on the table *D0* to access the data from the table *D*. Next, the update_query_statistics() operation logs the query in a log, which may be standard log of the DBMS. We use pgFouine to analyze the logs and to compute temporal statistics of of SELECT operations. For the purposes of testing, we perform some queries in the indexing_schema_maintenance() process and measure their duration. It calculates the mean $\mu(T_S)$ and standard deviation $\sigma(T_S)$ of the queries duration on *D*. Moreover, it calculates the mean value $\mu(T_{S\ DI})$ of the durations of accessing data in *DI* employing indexes and the mean value $\mu(T_{S\ D0})$ of the durations of the accessing data in *D0*.

Algorithm 3 Process indexing_schema_maintenance()

```
Input: user-defined constraints, table MD
Output: schema changes
Precondition: A signal "check RT constraint"
              or a batch of INSERTs
M[T_I] = μ(T_s) + n*σ(T_s);
if M[T_I] > T_I MAX then
   raise warning "Insufficient Hardware";
M[T_S] = μ(T_s) + R*σ(T_s);
E[T_S DI] = μ(T_s DI);
E[T_S D0] = μ(T_s D0);
if M[T_S] > T_S MAX or E[T_S D0] > E[T_S DI] then {
   create new virtual table D_I';
   if M[T_S DI] > T_S then
      exclude partition P_1 from DI';
   if E[T_S D0] > E[T_S DI] then {
      data in D0 make a new partition P_k+1;
      include partition P_k+1 into DI';
   }
   create indexes for DI';
   replace DI with DI';
}
```

In algorithm 3, expressions E[*X*] and M[*X*], in accordance with (1), stand for expected value and estimated maximum value of *X*. The first condition (if) in the algorithm checks the insert operation durations to meet the soft real-time constraint $T_{I\ MAX}$. If it is violated, the situation is just reported, because the ReTIn does not use any index while inserting the data, so there is no related overhead that could be reduced.

The second condition checks the temporal constraints and defines when the indexing schema operation should be performed. Until the condition is met, the balancing of the execution time of the full scan on *D0* and the index data access on *DI* is considered to be optimal. The indexing schema maintenance operation can be executed if one or both of the following conditions are met—The duration of select operations on the indexed data part are about to break the user-defined $T_{S\ MAX}$ or sequential selects last longer than the indexed ones. In such cases the schema is changed and indexes are created. The re-indexing process is accomplished by the atomic replacement of the deprecated logical index table *DI* with *DI'*.

You can download ReTIn on PostgreSQL implementation at http://www.fit.vutbr.cz/research/prod/index.php.en?id=129 under GNU General Public License.

Experimental Results

We used a dataset of meteorological observations em Global Surface Summary of Day Data (GSOD) [13] for experiments. GSOD is a product archived at the National Climatic Data Center (NCDC) to make a wide range of climatic data available to researchers and the public. The on-line data files cover the time period from 1929. They contain data from more than 9,000 stations. Each record contains the global summary of day data containing 18 surface meteorological means and maximums and other characteristics as temperature, dew point, sea level pressure, visibility, wind speed together with precipitation amount, snow depth and indicators for occurrence of fog, rain or drizzle, snow or ice pellets, hail, thunder, and tornado/funnel cloud summary. Although this is not typical data with critical real-time constrains, but their huge ammount, spatio-temporal and data stream nature and the general availability make them ideal for repeatable experiments.

The GSOD data were represented by an array of integers. Float values in the dataset were rescaled and converted into integers due to performance and memory saving reasons. Then the table *D* into which the data is stored in the database had schema *D* (*t*: timestamp, *d*: array of integer). ReTIn implementation based on the PostgreSQL 8.4 database management system and the Generalized Inverted Index (GIN) index, recommended for indexing of large arrays, ran on a server 2 x AMD Opteron 2435 (six cores, 2.6 GHz), 64 GB RAM and 2.5 TB RAID-6.

The goal of the first experiment was to show dependency of the execution times of insert and select operations on the amount of data in the database for given constraints $T_{I\ MAX}$ and $T_{S\ MAX}$. There were three approaches to access data used: unindexed data, GIN indexed data and by means of the ReTIn indexing schema. The experiment was evaluated on 500,000 records of 1950s GSOD data. Size of the table *D* was about 240 MB including the GIN index structure.

The methodology of the experiment was as follows: Records were sequentially inserted into the data table. Average and maximum execution times of insertions were measured for batches of 100 insertions. Average and maximum durations of queries were measured by a set of queries for batches of 1,000 insertions. The same set of queries with the *contains* array operator was used in the batches. A result set of queries contained 5–50 % of all records in the table. Execution times were measured by stored functions on the database server. They are equivalent to the EXPLAIN ANALYZE query. During this experiment we set both $T_{I\ MAX}$ and $T_{S\ MAX}$ constraints to 0.3 s and $R = 3\sigma$. The experiment was repeated three times to avoid random noise.

Figure 2 shows dependency of average and maximum execution times on the size of the table *D* without any index on data column *d*. This approach was very fast for insertion but execution times of queries increased linearly with the number of records. The 0.3 s time constraint was permanently broken for more than 460,000 inserted records in the table. This corresponds to our expectation because of the full scan access to data.

Figure 3 shows the same situation as in 2, when the GIN index on data column *d* was created. The problem of this approach is shown in Fig. 3a. There are many insertion execution time peaks between 110,000 and 180,000 records. The cause of this phenomenon is the necessity to re-build the index structure. The maximum execution time of queries exceeded the value 0.3 s of the $T_{S\ MAX}$ constraint many times.

The results for ReTIn are presented in Fig. 4. They show the benefit of the proposed indexing schema. Maximum insertion execution times in Fig. 4a, were all below the value 0.3 s of the $T_{I\ MAX}$ constraint. Execution times were slower only when the indexing schema maintenance operation was performed. Execution times of queries shown in Fig. 4b demonstrate the benefit of our approach—the ReTIn indexing schema combines a stable time of insertion with balanced query processing.

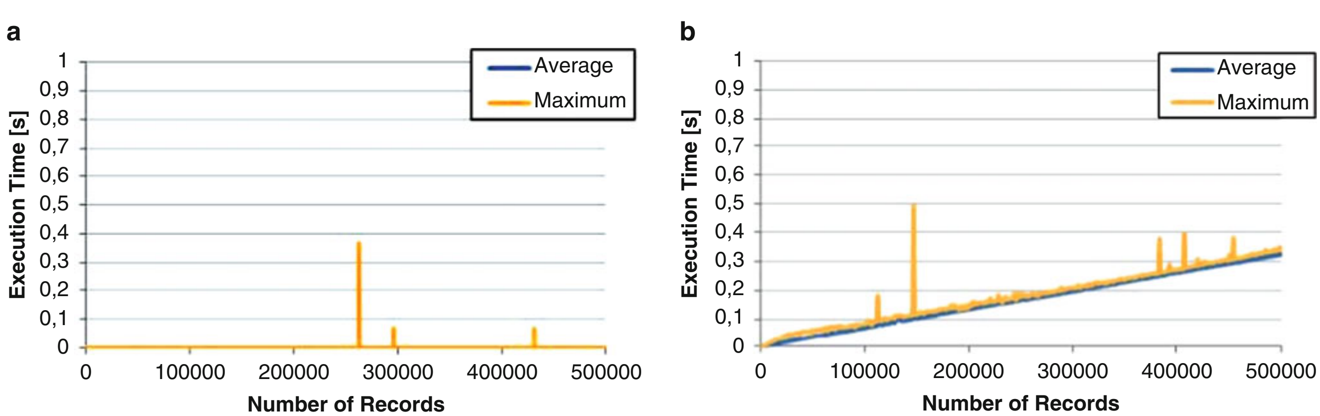

Fig. 2 Execution times of (**a**) insertions, (**b**) queries on the database table without an index on column *d*

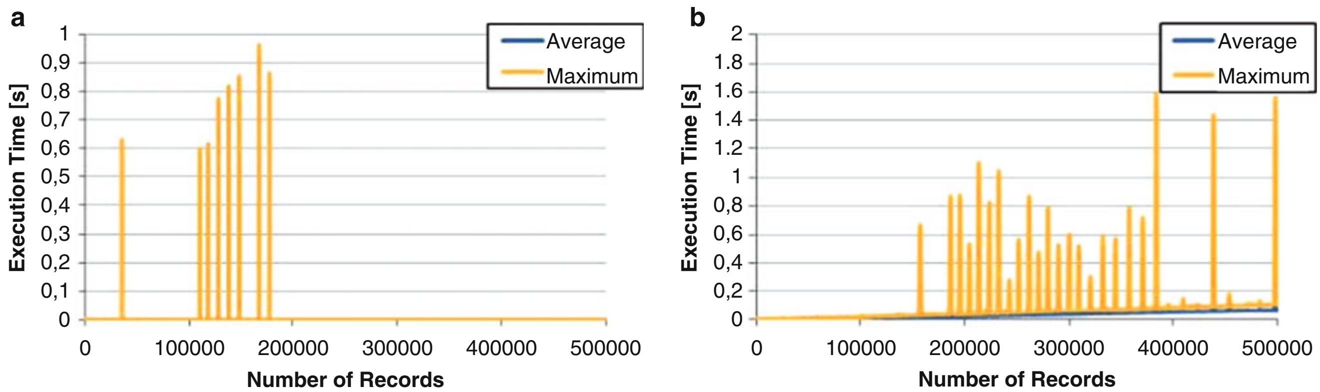

Fig. 3 Execution times of (**a**) insertions, (**b**) queries on the database with the GIN index on column *d*

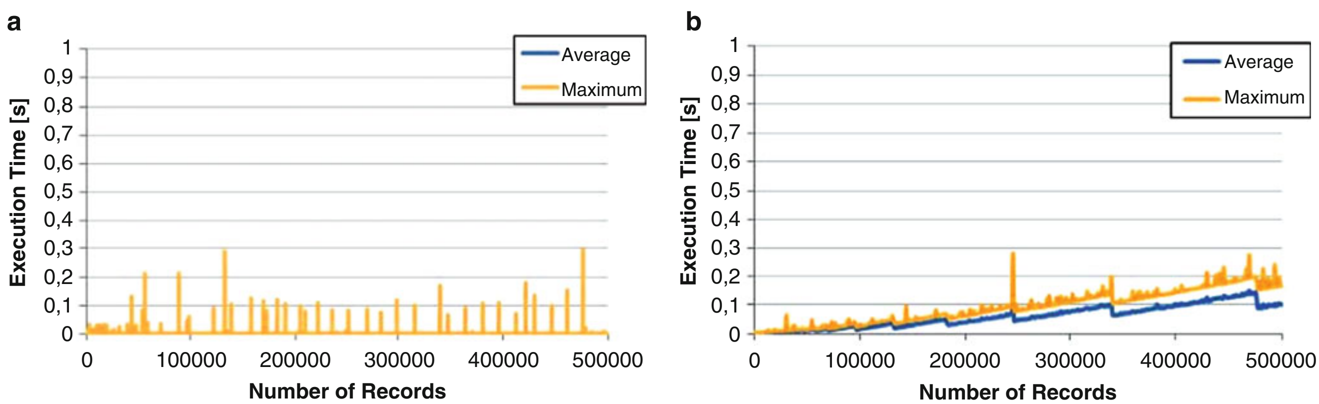

Fig. 4 Execution times of (**a**) insertions, (**b**) queries on table *D* of the ReTIn index schema

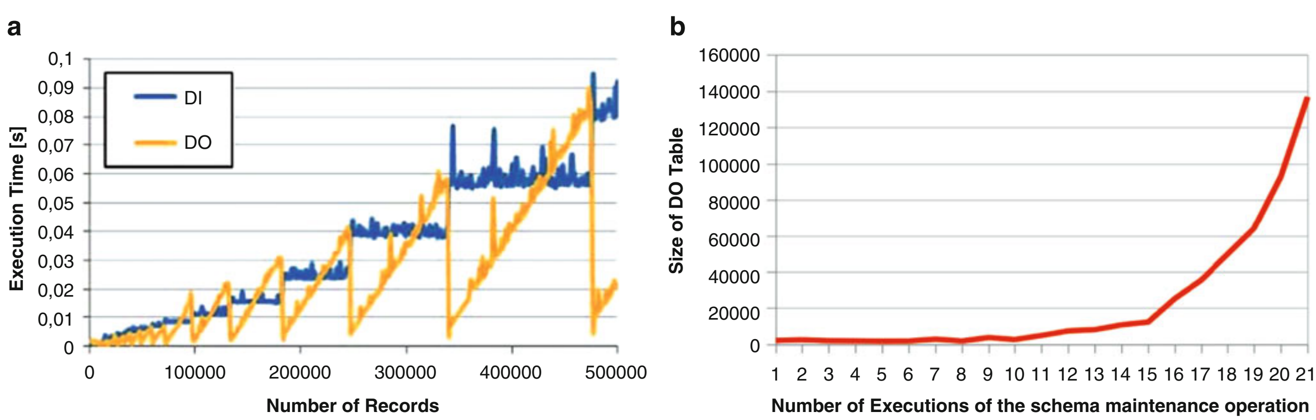

Fig. 5 Re-indexation aspects: (**a**) average times of queries on *D0* and *DI* tables, (**b**) dependency of the size of the *D0* table on the number of executions of the index schema maintenance operation

Figure 5 provides a more detailed view of the behavior of the ReTIn schema with respect to tables *D0* and *DI*. Figure 5a shows the decomposition of the average execution times from Fig. 4b to the times spent by partial queries accessing data in tables *D0* and *DI*. Figure 5b shows the dependency of the size of the *D0* table on the number of executions of the indexing schema maintenance operations. At the beginning, the full-scan search is very fast but grows linearly. As the

Table 1 The concurrency experiment

Threads	Queries failed	Inserts failed
	Using ReTIN indexing schema	
10 + 10	0.00 %	0.03 %
25 + 25	**0.52 %**	**0.31 %**
50 + 50	1.13 %	0.54 %
	Using simple GIN index	
25 + 25	**1.23 %**	**3.84 %**

number of records grow, more data is searched using the index and the total execution times grows logarithmically. It has proved our hypotheses stated in section "ReTIn Indexing Schema Concepts".

The second experiment was focused on the concurrency properties of the ReTIn. We simulated concurrent transactions by two groups of clients. The first one generated transactions containing an insert operation, the other queries. There were several threads running in parallel. We used the same set of data as in the first experiment. We evaluated the dependency of constraint violations on the number of parallel queries and insertions performed three times a second.

Table 1 shows main results of the experiment. We expected maximum violation rate about 0.3 % by setting the confidence factor $R = 3\sigma$. The experiment showed that ReTIn limit for *TI MAX* on this hardware is about 150 transactions a second—25 parallel insertions and 25 parallel queries three times a second (the row picked in bold in Table 1). This value also determines the maximum size of the data stream sliding window. For more transactions, the window size would have to be reduced to about 200,000 items for 300 transactions a second in our case. If we compare the same experiment with data stored only in table with a GIN index—see the last row in Table 1, which corresponds 150 transactions a second, we can see the benefit of ReTIn. It fails about twice less for querying and 10 times less for the data insertion.

Conclusions

We have proposed, implemented and evaluated a soft real-time indexing schema called ReTIn. It makes it possible to index a portion of a data stream stored in a database effectively and to meet real-time constraints for insert and select operations with some confidence. It combines storing the most recent data unindexed and indexing less recent data. The former is advantageous from insert operation point of view, but results in a full scan access for select operations. The latter provides more effective access to the rest of data. The indexing schema maintenance operation optimizes the balance between unindexed and indexed data access with respect to the real-time constraints. It is performed asynchronously to clients' insert and select operations, which are standard SQL queries.

The experimental evaluation showed advantages in comparison with indexing all data stored in the database. We used the efficient PostgreSQL's GIN index both in our ReTIn implementation and as a competitive access method in the experiments. They showed that ReTIn behaves appropriately for insertion and selection operations on both indexed and unindexed data in the database. Moreover, it changes its behavior automatically according to the system load—it changes the width of the sliding window that defines the number of data stream elements stored in the database.

The ReTIn framework does not specify the type of index used for indexing. Current DBMSs usually provide several types, some of them are suitable for indexing complex data, similarity search etc., for example KD-tree or R-tree. Their disadvantage often is high overhead of insertions. ReTIn can cushion this problem and allow indexing data streams containing complex data, e.g. spatio-temporal and arrays.

In the future, we intend to continue experimental evaluation of ReTIn with other types of indexes. In addition, we will focus on the ReTIn deployment and optimization for our surveillance network system SUNAR and the network security project, for which it was originally designed.

Acknowledgments This work has been supported by the research project Security-Oriented Research in Information Technology CEZ MSM0021630528, grant VG20102015006 of the Ministry of the Interior of the Czech Republic, the European Regional Development Fund in the IT4Innovations Centre of Excellence (CZ.1.05/1.1.00/02.0070) and with a financial support from the Czech Republic state budget through the Ministry of Industry and Trade.

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Self-Organized Teams: A Contradictory Technique to Motivate Personnel

Deniss Kumlander

Abstract
The self-organized team is a core technique in the modern software development methodologies known as agile techniques. It improves the ability of a team to make efficient decision and move a project toward the ultimate goal. This technique has been recognized as a motivational practice in many companies, while in others applying it produced a sufficient negative impact. In this article the meaning of the practice is revised. We study cases when applying it would have positive or negative effect and how we can improve the efficiency of that even in a negative case.

Keywords
Self-organized teams • Personnel motivating • Software engineering • Key success factors

Introduction

The software development is rapidly changing highly technological [3] business sector with shortage of employees and tough competition among software vendors. The software development process is a well-studied topic aiming to improve the ratio of success in software engineering. For example the invention of agile methodology has sufficiently decreased the gap between software engineering results and customers expectations, but wasn't able to eliminate software projects failures completely. We still name a project to be successful if it overcame budget not too much or if the ratio of used features is more than 50 % [1]. Therefore it is very important to understand the reasons for such failures as those add a sufficient extra amount to the overall cost of software engineering and affect a company ability to compete.

Among various reasons bounded to technologies or processes we use building software one is related to personnel. Software development is one of the processes where people play crucial role [2]. Their skills, abilities and involvement into the process define the success of the project through quality of the project, ability to build software following current and future customer needs, innovational thinking and technological knowledge allowing applying the right technique to construct the product. At the same time every company and country complains about sufficient shortage of skilled professionals. Companies carry very high cost losing their employees—to find replacements, educate them and train to the required standards. Therefore the motivation of personnel importance in software engineering sector grows rapidly especially considering that some standard motivational techniques [4–6] doesn't always provide required results or possible considering tough competition or specifics of the software engineering sector. One of such is dependency of the majority of modern software development techniques on the advance team work. All this motivated us to review, in the paper, two topics: motivating personnel and the self-organized teams, which are in fact the core of most modern approaches as provides the flexibility, dedication and goal-focused approach of a project team.

The first chapter below revises the importance of none material motivational techniques and outline main of them. The next chapter reviews the concept of the self-organized teams and maps its' properties to previously stated

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_51,

approaches to motivate employees. Thereafter we study different properties of the self-organized teams, their benefits and drawbacks in order to understand why this technique is so contradictory and what are hidden dangers applying it. Finally we discuss how some drawback can be neutralized as in many cases benefits are so sufficient that the wish to apply this kind of team persists despite of dangers.

When Material Motivating Techniques Are Not Enough

The professional and motivated personnel are a key element of the success in such highly technological and individuals based business sector as software development. The unqualified, unmotivated personnel seeking for a possibility to avoid dealing with tasks and problems is a major risk factor [4, 6] since they do:

1. Decrease productivity;
2. Produce defect output, handling which is more costly sometimes than building the quality one by more qualified and motivated individuals;
3. Leave the organization sometimes erasing from the "organization memory" important knowledge and forcing the company to invest into finding new personnel and educate them;
4. Ruin the co-work.

There are different techniques to motivate personnel and the most obvious are based on business promotions, cash or other rewards. Unfortunately it is not the available way to go in many cases. First of all due budget restrictions many companies have at the moment. Secondly the technological sector, in many cases, is based on satisfaction that people acquire working on one or another company and may not be related to benefits they get as those more or less similar across different software vendors that they may be working for. Moreover, sometimes people may leave the more rewarding (from material point of view) place due lack of interest, stress etc. and prefer the other place where they are "happier". The happiness is hard to measure, but it is clearly related to satisfaction and nonmaterial motivation process. Finally there are many places where individual work for been a part of society like teaching at universities, nonprofit software projects and so forth.

When we talk about other ways to motivate then normally we do mean the following techniques:

1. Employee recognition program;
2. Surveys and other reports showing the employee contribution into the project, his or her good work;
3. Enjoyable work environment;
4. Providing a possibility to affect the process, share opinion.

Self-Organized Teams

The self-organized teams can be described using the major property of those—ability to act fully autonomously during unrestricted period of time and can be recognized within the organization as a kind of "black" box receiving targets and tasks and producing required results within predefined constraints. Those teams do not require external management efforts and use several kinds of autonomy in order to ensure positive experience dealing with those.

There are different types of autonomy. First of all it is an external autonomy, which was already mentioned as an ability to act without management efforts constantly pushing the team in required direction and focusing them on targets. Obviously it doesn't mean that the team is expected to act absolutely independently since it is just a part of the organization. The autonomy here mean that the team is granted rights to decide by themselves and the influence of any teams, persons that do not belong to the team is minimized and is formulated just in form of targets or constraints defining the scope of the requirements arriving to the input of the team "box".

Secondly there is an internal autonomy that defines the team internal procedure of arriving to decisions and on what degree each member of the team is involved into this process. In most cases decisions are made jointly and in some rare cases this right is delegated to a restricted set of internal experts.

Finally there is an individuals' autonomy showing in which respect each member of the team has rights to pick up tasks and influence the tasks-to-persons assignment process. It also defines in what degree the person can set the sequence in which s/he does those tasks obviously following tasks interdependencies. A level of agreement shows how many tasks per person were not picked by team members and had to be assigned. For many successful teams this indicator will equal to zero as individuals will rather volunteer than bargain distributing tasks.

All this properties of the self-organized team make it to be one of the best choices for motivating personnel. It gives the recognition to the team as grants ability to decide how to achieve goals. It builds the trust and respect to the qualification of the team. It makes possible for each member to share their opinion and affect the process. Every member can discuss, listen and try something new, criticize and been criticized, recognize others efforts and been recognized. Finally it builds an enjoyable work environment working in a team and mostly eliminates the demotivation from having to do something a person do not want as he or she has an ability to select tasks or help others sharing own knowledge and skills.

Self-Organized Teams: Benefits and Drawbacks

Benefits of Self-Organized Teams

In this chapter we are going to revise additional reasons to apply self-organized teams besides earlier mentioned, which map to traditional motivational techniques that are not specific for software engineering.

First of all the self-organized team is a standard agile software development practice, which makes is to work. It is nearly impossible to be agile without self-organized teams, without benefits and mobility that kind of team provides.

Secondly the self-organized teams are used in many companies when we deal with pilot or risky novel projects. Why it can be an additional benefit? First of all because many such projects are challenging tasks and individuals see that they are recognized as having skills and level of knowledge required to be involved in such projects. Secondly such projects are nearly always projects involving new technologies, interesting novel approaches and practices. One of the main motivations for people of the certain age to leave a company is been bored with old techniques they used on the current workplace and been outdated. They would like to update their skills to obtain certainty regarding their future in the quickly changing technological sector where skills appear and outdate very quickly.

Thirdly the self-organized teams provides the cross training advantages. One of the demands in such team is the ability to help others playing in their roles as the team has not completed a task and consequently cannot pick up the next until every member of the team hasn't completed his tasks. It sufficiently improves involvement into other tasks, understanding the problems and technique the other role does use. The also allows spreading the knowledge and building the safe situation for case of losing somebody of the team: the knowledge is not gone, but remains within the organization and new people can still be trained to the same level. This also builds the respect to others' work.

Some people prefer to swap either periodically or temporary the work environment including their tasks and coworkers. Such people will like to be included into new projects with new team members. This will give them a feeling of global changes without leaving a company and consequently will help us to keep the knowledge within the organization. In some cases even temporary projects will allow them to be refreshed breaking the routine.

Drawbacks of Self-Organized Teams

Unfortunately self-organized teams are not always the best choice in all circumstances. There are a lot of examples when such teams were applied and that lead to local disasters. Therefore we would like to revise next symptoms that indicate a potential failure.

First of all such teams can be applied only in organization with certain culture. If management is not ready to grant autonomy, recognize teams ability to act independently then neither self-organized teams will work successfully nor we can talk about self-organized teams as a motivational technique. In most cases the team will be organized and management will constantly interfere into the process greatly demotivating the personnel as they will both fill uncomfortable and still managed and so been in a project leading to a disaster.

Secondly the self-organized teams can be formed and motivate only if individuals would like to participate in such. If they are very conservative, follow the down shifting perception of life and are afraid to communicate then self-organized teams will change their world in the negative direction. There are three potential scenarios:

1. They will be neutral been a part of such team;
2. They will destroy the team blocking the communication channels;
3. They will leave a company and find more "traditional" place.

Thirdly one important element of the self-organized teams is the increased freedom and consequently increased responsibility to deliver the right product in the right time tightly cooperating with other team members. Here the employee cannot rely any longer exclusively on himself or avoid the commitment. While some will rather feel relaxed as they share the responsibility, certain persons will fill a sufficient increase of stress—at least initially. If the person is unable to structure his tasks, plan the time then it leads to chaotic activities and rapid switching between tasks, that affect negatively his progress and only proves his believes of been not able to cope with the situation.

Thereafter the communication between people is not always a given ability or a simple element to ensure presence. In any team, but especially in the self-organized teams, the ability to listen and find tradeoffs is the important factor defining the success. If the team is composed of people not willing to cooperate or communicate then the team will never function properly, and the highly autonomous team will fail demotivating involved people. Therefore it is crucial to consider which employees to select into which team and how their skills will cooperate: will those overlap or complement each other. The stress can be also produced by new people, new environment, new technology to be used or new approaches to software engineering process.

Neutralising Drawbacks Applying Self-Organised Teams

The previously said raise a question: are drawbacks inevitable or we could do something to still gain the motivational part of that?

Culture

The first kind of barrier building up self-organized teams recognized in the previous chapter was the organizational culture. It is impossible to grant autonomies if management is not ready to do that. At the same time, as it was shown above, such management is not able to recognize and motivate personnel, so they may seriously reconsider their views in case professionals start to leave and so may choose applying self-organized teams as the first step on this road. Besides this kind of team sometimes misunderstood as is seen as a team, which do what they want without any transparency. In fact it should be made absolutely clear for the management that the team is not only granted with autonomies but also will have additional responsibilities. The transparency is ensured by the daily reports showing their progress toward the end goal and in fact is usually more transparent than a traditional team since it is interested in been transparent and honest regarding the progress. The management or product owners still control the set of features the team is working during each sprint on and the output by validating the deliveries every 2–4 weeks.

Ability or Willingness of Individuals to Try Something New

In one of our previous studies we have shown that personnel can be clustered by their ability to learn into:

- Innovating;
- Slowly changing/slowly learning;
- Static [7].

Additionally we should consider the learning factor per person, which is defined as a multiplication of his ability to learn, willingness to learn and an organization's wish to learn (motivate) this particular person. It is not advisable to include into self-organized teams persons having less than an average in that indicator.

It is also possible to include somebody into the self-organized team on a partly base—10 % of time for example highlighting the initial absence of commitment or high responsibility. He can be a consulting member as the knowledge transfer will still be an acquired benefit and may be later he will become a fond of such team/way of working, while the anticipation will not lead to dramatic demotivation results.

Semi-self Organised Teams

If the application of self-organized teams is impossible then it is reasonable to consider an intermediate approach, which is a semi-self-organized team. It is a type of teams that can act independently only during restricted period of time obtaining a certain level of autonomy of any kind, but rarely all of them. The advantages of this approach are:

- People are not afraid to be left alone in front of complex tasks. There is always a manager who is ready to help them organizing the work;
- Employees can try themselves in different roles as the controlled roles rotation within the team is one of techniques supporting the semi-self-organized roles [8];
- Some people are not able to use individual autonomy and prefer to be told what to do. One kind of the semi-self-organized team is the variation when one of the team members plays *periodically* the manager role. He doesn't take away autonomy from others but assists on demand;
- Co-work as involved members usually do different kind of tasks, which allows them better understand difficulties of other position tasks, reasons and motivations of decisions made by other people and better align them to his work tasks decisions.

Communication

The key element of the self-organized teams is improved flexibility and productivity through the enhanced communication. If an employee is not able to communicate efficiently he neither can be motivated via ability to share thoughts or affect the process nor be involved into self-organized teams in order to obtain the recognition and be innovative. Therefore it is important to improve gradually abilities to communicate with others that can be restricted due linguistic or behavioral characteristics of that particular person.

Conclusion

In this paper we have examined how the self-organized teams can be used as a motivational technique, why that kind of teams corresponds to main motivational approaches and when application of that is impossible. The self-organized team is not a silver bullet and therefore the manager planning to build such team should be careful selecting individuals into it and consider environmental factors like the organizational culture. Otherwise the result will not only be neutral, but even opposite—demotivate employees and forcing them to leave.

The paper also review the approaches that can eliminate the drawbacks of such teams still keeping all the advantages direct or indirect (like motivation through been innovative participating in new technology projects).

It is important to remember that applying the self-organized teams as a motivational factor we should remember to value the person opinion and recognize his rights not to participate in such teams or decrease the uncertainty in the environment. We should change his world only if it is absolutely necessary and value his commitment to our organization planning such changes.

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Pre-MEGa: A Proposed Framework for the Design and Evaluation of Preschoolers' Mobile Educational Games

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Abstract

With the spread of mobile games targeting preschoolers there is an increased need for the creation of high-quality, research-based content for this age group. But how can "quality" be defined here? To answer this question, an extensive review of literature and available rating systems was needed which resulted in a detailed set of attributes which constitute a fun, usable, beneficial and, above all, successful mobile learning game targeting preschoolers. This framework (Pre-MEGa) is presented in this paper with the aim of facilitating the process of translating research into concrete, measurable characteristics for designing and evaluating this type of software.

Keywords

Educational technology • User-centered design • User interfaces

Introduction

Games are the most popular digital activity for children from age two, especially on mobile devices [15]. In the USA, on a given day, approximately 40 % of all preschoolers play video games on consoles or mobile devices [4]. One of the most special advantages of educational digital games for children is their potential to positively affect their attitudes toward learning [18, 19, 28, 31, 32]. This is due to several factors:

- Graphics, sound and movement capture children's interest more than text and still pictures in books and flashcards.
- Challenge and competition experienced with games wrap the educational content with more excitement than the passive nature of non-interactive media.
- Random access and parallel processing free young children, who naturally have a short attention span, from the constraint of a single path of thought.
- The immediate reward is a motivation for perseverance which is more meaningful to young children than long-term rewards.
- The low level of threat associated with failure in games builds self-confidence and positively connects the child with the learning experience.
- Fantasy and stories of game characters attract young children to indulge in an emotional experience similar to their beloved fairy-tales.

All of the above factors contribute to the outcome that children would rather spend more time playing games than studying using traditional media: The long time children can spend playing games makes games an incredible opportunity for learning. Touch screen devices allow children to interact with technology at a younger age than ever before. Very young children who used to have problems using a mouse as

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_52,

an indirect pointer to hit a target or playing using joysticks can now navigate a tablet touch screen intuitively and with ease [9]. Mobile Games-Based Learning joins both playful education and mobility to achieve an even more natural environment for learning and is among the most recent growing research areas as apps are rapidly emerging as a new medium for providing educational content to children. According to a study carried out this year, 2012 [30], over 80 % of the top-selling paid apps in the education category of the iTunes Store target children. Unfortunately, when deciding to develop serious mobile games for preschoolers, the designer is faced with many challenges:

- Research in this area is still immature and there is (to our knowledge) no comprehensive set of guidelines dedicated to this category of software and targeting this age group.
- Wrapping educational content in a fun and appealing game which preschoolers will prefer over non-educational games is not an easy task.
- Keeping preschoolers' interest to repeat playing the game over a long period of time to benefit by reinforced learning is a major requirement otherwise the whole project will be useless: Unlike older school children, preschoolers will not play with it as part of a curriculum or even play with it with the incentive of learning. Under no circumstance should the fun aspect be sacrificed in this kind of project for any other consideration.
- The inability of preschoolers to read requires a big audio library to be created which adds to the cost and time needed for the already expensive project and without proper guidelines for multimedia learning creation, the overhead might grow due to late corrections.
- Testing with preschoolers is difficult and time-consuming, thus it is vital to know in advance what to expect to design accordingly.

However, there are also advantages of creating learning games for this young age over designing for older children:

- Learning material for this age group is simple and straightforward. There are no complicated theories which are difficult to convert into a fun game.
- Preschoolers' perception of a game is still limited to simple activities without the need for "real" game strategies and complicated scoring.
- Preschoolers are not required to master a large amount of learning content but rather have fun while indirectly acquiring new skills and recognizing new concepts. The real aim of educational games targeting this age group is to increase their motivation and passion for learning to make them ready for later instruction in school.

With these considerations in mind, we have attempted to develop a set of heuristics for combining play, learning, usability and mobility requirements which can be used in evaluating and comparing available products targeting preschoolers but also, and more importantly, in early stages of product development.

The Development of the Framework

The framework is intended to ease the process of designing and evaluating mobile learning games for preschoolers by providing an easy-to-use checklist combining the parts matching our category from different guides and rating systems. For the gathering of requirements we have depended on both formally published research and already applied review systems. The following are examples of resources which we have considered in our research:

- Structured Expert Evaluation Method (SEEM) [5]
- Children Interactive Media Evaluation Instrument (CIMEI) [12]
- The new Yogimeter by YogiPlay for Evaluating Children's Learning Apps [1]
- The Common Sense Media Review System for Children's Video Games [2]
- The Preschoolers' Likeability Framework [7, 8]
- The HECE Framework of Usability Heuristics for Child E-Learning Applications [3]
- The Enali Framework for Pedagogical Agents [13]
- Malone's Heuristics for Designing Instructional Computer Games [23]
- Prensky's Digital Games-Based Learning [28]
- Playability Heuristics for Mobile Games [20]
- Other Heuristics for Video Game Design [27]
- Research on Mobile and Touch Interaction of Young Children [9, 29]
- Design Principles of Educational Virtual Worlds for Preschool Children [26]
- Principles for Evaluating Children's Interactive Products [16, 24]
- Other Research on Child Computer Interaction [6, 10, 14, 17, 21]

From each set of heuristics we have extracted the features compatible with our topic. This resulted in clusters of attributes which we have rearranged into broader categories and subcategories. As a result, the framework was divided into the following 15 categories:

1) screen design, 2) navigation and control, 3) ease of use, 4) responsiveness, 5) game design, 6) learning potential, 7) instructions, 8) feedback, 9) difficulty level, 10) content delivery and presentation, 11) pedagogical agent, 12) customization, 13) security, 14) accessibility, 15) value.

The Pre-MEGa Framework

The Pre-MEGa Framework consists of 15 categories of guidelines for the design of a successful educational mobile game for preschoolers. It can be used for both design and assessment of this category of software and covers aspects of learning, usability and game play taking into account the specific age group and the mobile touch screen aspects. We hope that this framework might serve as an easy-to-use and comprehensive checklist compiled from literature which makes it easy for designers from any background to directly translate to specific design requirements. Table 1 shows the proposed Pre-MEGa framework divided into categories and sub-categories and associated with references from literature and rating systems.

Using the Pre-MEGa Framework

The proposed framework can be used in several ways. First it can be used to define concrete design requirements for individual applications which are translated from the heuristics. As most of the time it is not feasible to fulfill all the requirements of the framework, this step should follow the step of defining design objectives. A useful model in this regard would be the PLU-E Framework [33] which is based on the PLU Model described in [24] (See Fig. 1). Using this framework, the designer or evaluator determines a percentage for each of the three variables, P (*Playing*), L (*Learning*) & U (*Using*) to map his product onto the PLU Model and determine the suitable evaluation method accordingly. Although this framework was not intended to be used in our context, we find it to be suitable for defining design and evaluation priorities by redefining the U to be for *Usability*. For example, if a product is created mainly for fun with only marginal emphasis on learning, then our heuristics listed in the fifth category would get the highest priority while those in the sixth category would be less important to fulfill. After sorting the categories by priority, it would be easier to decide which design requirements should be fulfilled within the specific project constraints. Another way to use our framework is for implementing and documenting improvements in newer versions of software. It can also be used to evaluate and compare available products by specifying weight to different categories and obtain an overall rating (as done in the CIMEI and Yogimeter rating systems, for instance).

Conclusion

With the emerging of new technologies, the criteria for assessing the quality of children's products need to be constantly updated to reflect their new interaction trends. In this paper we have proposed a framework for the design and evaluation of preschoolers' mobile educational games. This is intended to serve as a theoretical basis summarizing previous research and updated with new trends which can be further assessed, enhanced as well as adapted to different specifications and target users. We hope this framework will also be adopted into new or incorporated into an available rating system for reviewing and comparing available products in this category.

Table 1 The pre-MEGa framework

Category	Subcategory	Guidelines/heuristics
Screen design	Menus	Clear picture menus without text [12] Consistent design [12] Layout efficient and visually pleasing [20] Similar learning objects are organized in a similar style [3]
	Icons	Visually meaningful [16] Large, easy to select [12] No phantom icons [12]
	Mobile and touch specifics	Cautious Response with tilt functionality [29] No buttons near screen edges [9] Simplified screens, adaptable to different sizes [29] Using device interface and game interface for their own purposes [20] Consistent control keys following standard conventions [20] Interruptions are handled reasonably [20] Accomodation to surroundings [20] Sessions can be started quickly [20]
Navigation and control		Simple one layermenus with direct access [11, 12, 17] Consistent, logical and minimalist controls [20] Help Kids know where they are [12, 20] Remember things already discussed [12, 17] Choices to select strategies (even if insturctionally irrelevant) [14] Control over rate and order of display [12] Clear exits from all sub-games [5, 12, 20] Main menu accessible everywhere [12] No irreversible errors [20]
Ease of use		Require age-appropriate skills only [12] Bigger areas for selecting, dragging and tracing [17] Enable independent use after first use [12] Consistent responses to user actions [27]
Responsiveness		Short, interruptible routines and animations [12, 27] Let kids accidentally succeed in the first 30 s [12, 20] Quick, clear response to touch and no stagnation [12, 20, 27]
Game design	Game type and scope	Combine simple exploratory non-goal-oriented games with more sophisticated goal-oriented games [11, 25] Support different playing styles [20] Offer a chance for creativity and self-expression [7, 8, 20] Include collaboration options [8]
	Game story	Supports game play and is encouraging [20] Offers a social experience [8] Fosters imagination [7, 8] Provides positive role models and messages [2]
	Challenge elements	Set a clear, fun goal which quick subgoals [5] Clear, fun and physically age-appropriate actions to reach the goals [5] Balance challenge, strategy and pace [20] No repetitive or boring tasks [12] Visible reminder of progress [20] Offer some uncertain outcomes [20, 23] Convenient, flexible, game controls [20] Support player-created goals [20] Option to compare results [20] No loss of any hard-owned possessions [20]
Learning potential		Offer sufficient amount of content [12] Provide deeper, applicable learning [1] Make connections to authentic uses of learned content [1] Include sels-assessments to advance child achievement [3] Report advances of child [1, 12] Embed teacher/parent options [1, 12]
Instructions		Age-appropriate, easy to understand and remember [16, 20] Supportive rather than distracting [16, 12] Using clear-speech [12] Integrated in the context of the problem [12]

(continued)

Table 1 (continued)

Category	Subcategory	Guidelines/heuristics
Feedback		Frequent, variable, age-appropriate, context-related [10] Employs meaningful graphics or sound capabilities [3, 12] Descriptive, non-evaluative [13]
	Positive	Motivational [16] Attractive, fun, humourful [10]
	Negative	Let children know if they made a mistake [12] Offer helpful hints to correct actions [3, 12]
Difficulty level		Activities resembling adults' which look "difficult" [8] Include suspense and "danger" without leading to fear or frustration [3, 8] Offer different levels of difficulty and/or expandable complexity [10, 16, 17, 21] Do not underestimate or talk down to kids [12]
Content delivery and presentation		Use a theme meaningful to children [12] Embed in fantasy contexts [3, 14] Based on real-life experiences and related to socio-cultural context [10, 17, 21] Introduce concepts through many entry points [17] Divide information into smaller chunks [17] Use verbal rehearsal to foster memorization [17] Support with high quality graphics, audio and visual effects [3, 7, 10, 20] No graphics detracting from educational intention [3, 12] Use music and songs [7, 11, 22] Use cartoon characters which are either like the child or from his own culture [3, 11, 22] Multimedia elements assist and are consistent with the learning process [3] Use "Surprises" and employ random generation techniques [3, 8, 12] Use humor, paradoxes and interesting stories [3] Give kids unusual or exaggerated powers [12] Vary activities during learning sessions to avoid boredom [3] Illustrate abstract concepts with concrete examples [3] Use novel ideas and techniques for learning [3] Stimulate further inquiry [3]
Pedagogical agent	Interaction	Responsive and reactive to help requests [13] Redundant [13] Asks for feedback [13] Balances on-and off-task communication [13]
	Message	Appropriate to receivers abilities, experiences and frame of reference [13] Verbal matching non-verbal message [13] Clearly owned by agent [13] Complete and specific [13] Describe feelings by name, action or figure of speech [13]
	Characteristics	Attractive [12, 13] Free of gender or ethnic bias [2, 12] Establishes credibility and trustworthiness [13] Establishes a role and relationship to user/task [13] Polite and positive [13] Expressive [13] Context-appropriate visual representation [13]
Customization		Possibility of personalizing experience through own voice or avatar [1, 12, 26, 27] Adapting difficulty level to progress [1] Makes experience adaptable to gender or gender-neutral [6, 8, 12, 17] Adjustable sound which can be toggled [12, 27] Availability in different languages [22] Saving child's creations [1, 12] Customized, individualized feedback [12] Offers choice of scope, themes or playing styles [1, 7, 12, 27]
Security		Ensures privacy of personal information [1, 2] Free from ethnic bias, violence, scariness, inappropriate language or behavior [2, 12] Free from inappropriate ads, ads which detract from content, or lead to accidental purchases. Includes parental control options.
Accessibility		Can be used on a variety of devices [3] Available in different languages and countries.
Value		Over-delivers and undersells [12]

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A Review on Three Dimensional Facial Averaging for the Assessment of Orthodontic Disorders

Syed M.S. Islam, Mithran S. Goonewardene, and Mauro Farella

Abstract

The introduction of rapid, non-invasive, and reproducible imaging technology such as three dimensional (3D) surface scanners, Cone Beam CT (CBCT) and low-dose CT have made it possible to develop tools for evaluating facial morphology and accurately planning dentofacial surgery. Facial averaging using 3D facial data is one such effective tool. This paper comprehensively reviews different techniques of facial averaging and their clinical applications. All the approaches are classified according to their methodologies and their scope and limitations are discussed. Future research directions are also identified.

Keywords

Three dimensional imaging • 3D average face • Facial norms • Dentofacial deformities • Distance map • Geometric morphometrics • Facial landmarks • Facial growth • Gender and ethnic difference

Introduction

With the advancement in modern technology the accuracy of digital imaging has been improving and the cost has reduced dramatically. Three dimensional imaging is now become a reality and has applications in many spheres such as in security and identification, manufacturing, entertainment, robot navigation and forensic applications. 3D Computed Tomography (CT) images are routinely used for diagnosis and treatment planning in the medical area. However, due to the high radiation dose, CT images are requested cautiously for dental treatment. The introduction of rapid, non-invasive, and reproducible means such as Cone Beam CT (CBCT) and low-dose CT technology is now changing the way clinicians perform surgical and non-surgical procedures in the facial region [1]. Cone Beam CT and low-dose CT have been shown to be valid and reliable even for evaluating facial morphology in children [9, 18].

Facial averaging is an active area of research in many fields including Psychology in analyzing facial attractiveness [28–30] and Biometrics in face recognition [31, 32]. In Orthodontics, a gender, age and ethnicity specific facial average, also known as facial norm or reference frame is an essential tool for diagnosis and treatment planning for any orthodontic disorder involving dentofacial deformities. Such facial averages help estimating the changes required by the surgical treatment. Traditionally, such averages are developed based on clinical photographs or a set of radiographs (lateral cephalograms and panoramic views) [12]. All these 2D media are confined to the 2D representation and contain a patients' information within the single-plane image [4]. While projecting the human face (which is 3D) on the 2D plane, they lose important information and hence are prone to clinical inaccuracy. Most of the articles in the area of Orthodontics use primitive approaches of 3D facial averaging. However, this is an active area of research

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_53,

in the area of Computer Vision especially for facial recognition and more sophisticated algorithms have been proposed. In this article, we have explored most of those approaches which would help analyzing dentofacial deformities and generating the treatment plan more accurately.

There are only few review articles available that describe 3D facial averages applied for the analysis of orthodontic disorders. Three dimensional facial averaging is described in [24] as a part of the review on the techniques of 3D facial data analysis for various craniofacial applications. Hammond et al. [7] also describe this technique in their literature review on Computational Modelling used in craniofacial analysis. However, both of these articles only described the methods proposed by their research group. Kau et al. [14] mentioned some studies using 2D and 3D facial average/templates without any detail description. Most recently, Hammond [6] has summarized some studies applying facial averaging in the analysis of facial dismorphology. In this article, we have made a comprehensive and up-to-date review of all major articles using 3D facial averaging.

The rest of the paper is organized as follows. Available three dimensional imaging technologies used in Orthodontics are summarized in section "3D Imaging Technology". Techniques for constructing 3D facial average and methods on how to use them are described in section "Techniques for Constructing 3D Average Face" and "Analysis Using Facial Averages" respectively. Various applications of facial averaging are summarized and tabulated in section "Current Applications of Facial Averages in Otrodontics". The challenges to be met for improving the existing methodologies are outlined in section "Current Applications of Facial Averages in Otrodontics" and the conclusions are provided in section "Conclusion".

3D Imaging Technology

Three dimensional imaging technologies suitable for capturing facial data can be broadly divided into surface imaging and volumetric images. Laser scanners and streophotogrammetry are the two most commonly used surface imaging systems [8]. Laser scanners use laser rays to acquire depth information while stereophotogrammetry projects a light pattern or mesh onto different regions of the face. 3D reconstruction is then performed to develop 3D surface image. Volumetric images may provide bony structure as well as soft-tissue facial information and can be captured by MSCT, CBCT, MRI and ultrasonography. Each of the techniques has its own merits and demerits which are summarized in Table 1.

Techniques for Constructing 3D Average Face

Landmark-Based Approaches

Three dimensional facial averages can be constructed using a number of landmark points on the facial images. Similar the approach using two dimensional facial data, a set of landmark points is selected on each image and the three-dimensional coordinates (X, Y and Z) of the corresponding landmarks are averaged across all images. This averaged landmark configuration is then used as a template into which each image is warped. A texture image is produced by two averaging the grey-scale or color values. This way of representing a three-dimensional object using the two dimensional data hold similar problem of altered facial parameters due to warping. Since the face is reduced to a small number of data points, facial topography cannot be evaluated [24].

Landmark-Independent Approaches

In these approaches, the facial average represents the average of the Z (depth) coordinates of all pixels of the facial images instead of limited number of landmark points. Kau et al. [16] created a facial average using tools available within RF4 software. At first, they pre-aligned the images by determining the principle axis of rotation (based on computing the tensor of inertia of each 3-dimensional image). They used manual positioning, when necessary, to improve the previous stage. A best-fit alignment was then performed using the in-built algorithm in RF4. The averaging of co-ordinates of the images was performed normally to a facial template and then triangulated the derived point cloud to obtain the facial average. Small holes were filled and color texture applied on the average face.

Shaweesh et al. [21] used 3D-Rugle3 to prepare and export the 3D images for averaging. They exported each 3D image as an Excel spreadsheet with 256×256 cells representing the depth coordinates of the image pixels. Then they computed the average of the spreadsheet using MATLAB and exported the average spreadsheet to 3D-Rugle3 for visualization and comparison. Prior to the averaging process they performed alignment of all the images by bringing the Frankfort plane approximately horizontal. They also translated the images in X (horizontal),

Table 1 Summary of the available 3D imaging techniques for producing facial averages

Imaging technique	Advantages	Disadvantages
3D laser surface scanning	Accurate data	– Harmful to eyes (if taken closely) Long acquisition time – Multiple scanners necessary for textured surface high costs – Sensitive to light and metal objects
Stereophotogrammetry	– No radiation – Accurate and metrically correct data – Short acquisition time (2 ms) – Textured surface soft tissue – Low costs	– Poor accuracy eye lenses – Poor accuracy of subnasal and submental area
MRI	– Acquisition time of 40 s or less – No ionizing radiation – Accurate information of different layers soft tissue	– High costs – Horizontal scanning position – No textured surface data – Long acquisition time
CBCT	– Upright scanning position (in a natural head position) – Reduced ionizing radiation than MSCT – In office scanning and easy accessibility – Potential for generating all 2D images (e.g. orthopantomogram, lateral cephalogram, TMJ) – High resolution (e.g. bone trabeculae, Periodontal ligament (PDL), root formation) and less disturbance from metal artifacts – Reduced costs compared with MSCT – Digital Imaging and Communications in Medicine (DICOM) compatibility	– Relatively more noise in data and low contrast range – Limited inner soft tissue information and increased noise from scatter radiation and concomitant loss of contrast resolution – Movement artefacts affecting the whole dataset – Truncation artifacts (caused by the fact that projections acquired with region of interest
MSCT data	– High quality images	– Horizontal scanning position – High dose ionizing radiation and high amount of streak artifacts – High costs and out of office imaging
3D ultrasonography	– Low costs – No ionizing radiation	– Time-consuming – No textured surface and deformation of soft tissue due to contact between probe and skin

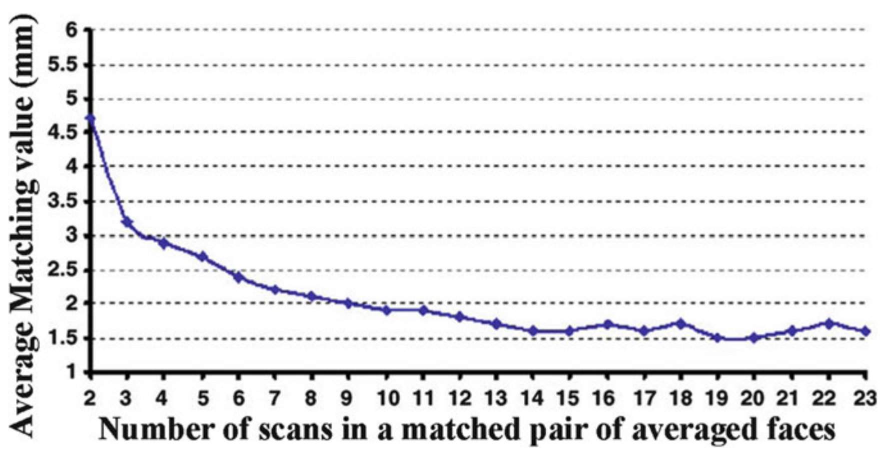

Fig. 1 Number of scans versus average matching value resulted from averaging of similar plots for six different populations [21]. Note that the plateau starts at 14 indicating the required number of scans to produce reliable average for a group

Y (vertical) and Z (depth) to align them with respect to the 'subnasale' point of the first image. The 'nasion' point in each image was then brought to the same X and Z coordinate values of 'nasion' in the first (reference) image. This helped aligning the images of various heights with the facial midline parallel to that of the reference image. As illustrated in Fig. 1, their experiments with average faces of six groups prove that scan number as low as 14 may produce reliable average for a group; which is significant especially in cases where it would be difficult to recruit samples with larger numbers of subjects such as individuals affected by rare abnormalities.

Analysis Using Facial Averages

Landmark-Based Analysis

(1) Geometrical morphometrics: Geometrical morphometrics [23], a method based on Cartesian coordinates of landmarks that retains all geometrical information in the data throughout an analysis, including location and orientation can be used for alalyzing landmark points. However, it requires that the coordinates of the points are recorded in relation to reference axes and all facial images are registered on the same plane of reference [24].
(2) Generalized Procrustes Analysis (GPA): Landmark coordinates can be analyzed using GPA as it allows comparing multiple faces with an average constructed face [24]. In this method, all faces are firstly rotated and translated to minimize the squared summed distances between the corresponding landmarks on each 3D facial image and the average constructed face. Images are also scaled to the same unit size (termed as "centroid size"). Then a direct comparison between landmarks is performed that reflects the differences in shape.
(3) Principal Component Analysis (PCA): PCA helps highlighting the variability of studied sample. This algorithm is based on orthogonal transformations and allows the reduction of an original set of data with possible correlations to another set of uncorrelated variables, known as "principal components" [23]. Therefore, it can be used to reduce the variation associated with landmark position to a much smaller number of principal components [24].

Landmark-Independent Analysis

An average face can be superimposed on to a face and the surface difference between the faces can be quantified in millimeters as mean differences between all points from one surface to another. Color histogram can be used to visualize these differences by representing the differences across a color spectrum with values associated with each color.

Current Applications of Facial Averages in Otrodontics

Development of Facial Aesthetic Norms

Aesthetic norms/standards are developed by averaging beautiful faces. These averages have been used by clinicians to compare the results of their treatments. Moss et al. [19] developed similar norms by averaging faces of 9 men and 15 women who were professional models. They also developed separate averages of 40 men and 40 women and compared those with the norms. They found some differences in width and, prominence in lips and chins.

Ethnicity Analysis

It is important to have norms for various groups as we live in a multi-ethnic society. Tiddeman et al. [22, 25] used facial averages of two population groups to compare their facial morphological differences and to analyze the facial variation in a sample of a single population. Shaweesh et al. [21] developed population norm out of 70 European males, 33 European females, 70 Japanese males and 32 Japanese/Korean females and compared their facial morphologies.

Moss et al. [19] developed the average for a group of Asian women and the average for a group of Asian men and compared those with similar averages of European men and women. They demonstrated that there are considerable differences between these groups and the European averages recommending tailoring the norms as closely as possible to the individual while assessing the results of treatment.

Facial morphology of 473 subjects of five different populations is analyzed in [15] using 3D facial averaging. Linear differences between surface shells are reported as ranging from 0.37 to 1.00 mm for the male and from 0.28 to 0.87 mm for the women groups. Their results also confirm that the greatest facial morphologic differences exist between totally different ethnic variations and the most similarities are present in comparable groups, however, with large variations in concentrated areas of the face.

Gender Analysis

Using average face technique on 59 children age between 12 and 14, Kau and Richmond [13] reported surface changes are greater in boys than in girls; and the differences in the timing of surface changes in boys and girls are clinically significant, with boys exhibiting more changes later. The same research group constructed separate facial averages of 42 boys and 30 girls and reported the difference between the average male and female face as 0.460 ± 0.353 mm [16]. They also found the areas of greatest deviation were at the zygomatic area and lower jaw line, with the males being more prominent.

Toma et al. [26] computed separate average faces of 166 female and 184 male British-Caucasian children (age between 15 and a half year) and compared those to analyze gender differences in facial morphologies. They reported that females tend to have more prominent eyes and cheeks in relation to males with a maximum difference of 2.4 mm; whereas males tend to have more prominent noses and

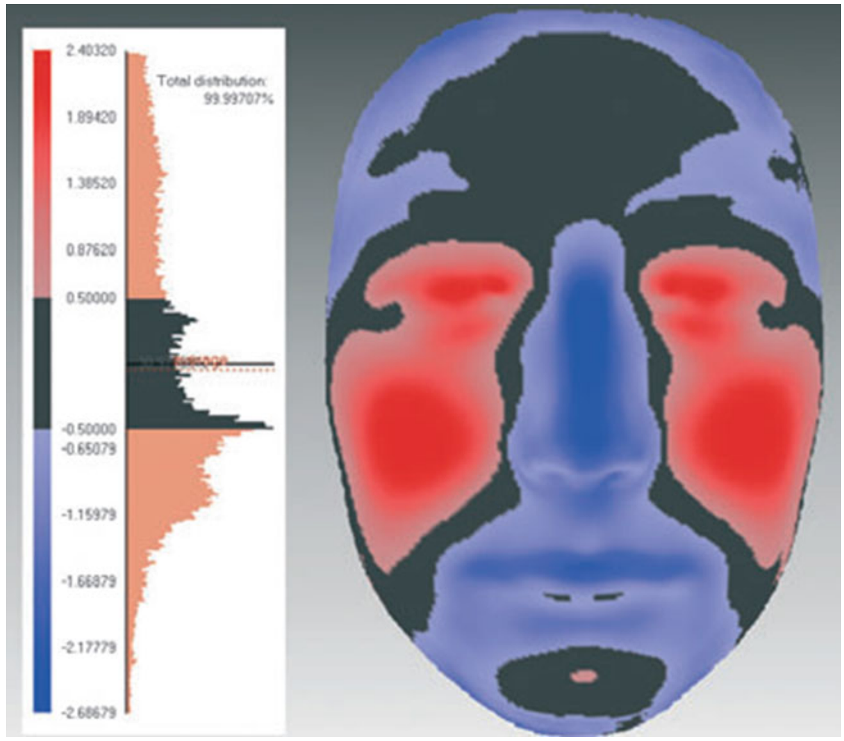

Fig. 2 Comparison of the facial morphology of average male and female as computed in [26] (best seen in *colour*)

mouths with a maximum difference of 2.7 mm. They also observed that about 31 % of the facial shells match with no difference, mainly in the forehead and chin regions of the face (see Fig. 2).

Bugaighis et al. [3] analyzed gender difference in facial morphologies of 39 male and 41 female Caucasian children aged between 8 and 12 years. They developed 3D average face for each of the gender groups and compared each face against that average. They used GPA and PCA to measure shape variations. Analysis of covariance and Pearson correlation coefficients were used to explore gender differences and to determine any correlation between facial measurements and height or weight. Multivariate analysis was used to ascertain differences in facial measurements. They found no differences in height or weight between genders but a significant positive correlation between facial measurements and height and weight and statistically significant differences in linear facial width measurements between genders mostly related to the larger size of males rather than differences in shape.

Growth Analysis

Facial averages are useful for assessing the amount of growth failure in patients with craniofacial microsomia. In this condition, there is a failure of growth of one or both sides of the face, resulting in gross facial deformity. Comparison with the growth of a normal individual at the same age is possible by registering the scans of the patient with the norm for that age. In this way, the exact amount of the deficiency of the growth can be quantitatively assessed.

Nute and Moss [20] generated 3D facial averages from 3D scans of children to study their 3D growth of the facial complex. Facial growth is also analyzed in [13] on 59 children (age between 12 and 14 years) over a 2-year period. In that work, average face of the children was used as reference to measure the surface changes. A downward and forward change in surface area with respect to the nose and soft-tissue nasion is reported. Positive surface changes are observed occurring in the nose, brows, lips, and vertical dimensions of the face, and the eyes deepen, and the cheeks become flatter.

Kau et al. [11] performed a 2-year longitudinal study of facial growth in a child who had undergone segmental resection of the mandible with immediate reconstruction as a treatment for juvenile aggressive fibromatosis. They acquired a 3D scan of the child at immediate, 6 months, and 2 years post-resection. They used an average female face constructed in a previous study as a reference for a normal growth pattern. After processing and superimposition, they used shell-to-shell deviation maps for the analysis of the facial growth pattern and its deviation from normal growth. The changes were recorded as mean surface changes and color maps were used for visualization.

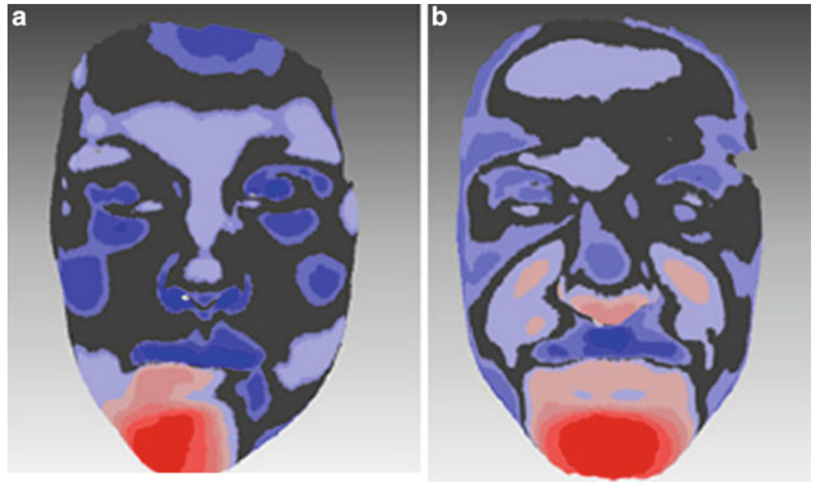

Fig. 3 Asymmetry in the Slovenian female (**a**) and male (**b**). Class III faces while superimposed on an average Slovenian female and male face template respectively [2] (best seen in *colour*)

Facial Asymmetry Analysis

Božic et al. [2] evaluated facial asymmetry in 14 male and 15 female adult Slovenian Class III faces by comparing those with the average facial templates constructed from 43 male and 44 female Class I subjects. As illustrated in Fig. 3, they found that Class III faces tend to have a left-sided chin deviation.

Facial Movement Analysis in Patients with Cleft Lip and Palate

Trotman et al. [27] developed a normal scale of movement by developing an average face of eight noncleft 'control' subjects. They used this normal scale to analyze the facial movement in 16 patients with cleft lip and palate. They demonstrated this technique as more appropriate than the measures of mean movement differences as summarized by PC scores between patients with cleft lip and palate and noncleft subjects. They found the latter may be misleading because of extreme variations about the mean in the patient group that may neutralize group differences.

Analysis of Other Dentofacial Deformities

Hutton et al. [5] used archetypal face averages to visualize and recognize shape differences across and within syndromes. Binder syndrome (also known as maxillonasal dysplasia), is an uncommon developmental anomaly characterized by an unusually flat, underdeveloped midface, with an abnormally short nose and a flat nasal bridge. The facial morphology of a 12 year old boy with this syndrome is analyzed in [10] by comparing his facial scan with the average face of 42 nonsyndromic boys at age 11.5 years with Class I skeletal relationship, who had not received orthodontic treatment. The superimposition of the patient's face on to the average face allowed visualization of the Binder deformity and highlighted the gross deficiency of the nose (about 15–17 mm) and the maxilla.

Shaweesh et al. [21] analyzed Williams syndrome (21 subjects), achondroplasia (17 subjects) and Sotos syndrome (5 subjects) using their facial averages. They generated two averages for the first two syndromes: one for the subjects of ages over and another under 12 years. All the subjects with Sotos were over 12 years of age.

Krneta et al. [17] evaluated dentofacial deformities in 25 Class III children (9 males, 16 females) by comparing their facial surface images with the respective male or female average faces of a control group of 46 non-Class III children (21 males, 25 females) aged 5–6. The group comparisons were evaluated using an analysis of variance and color deviation maps with respect to facial height, facial convexity, mandibular position and facial surface morphology. They found that Class III children have less mid-face prominence and a concave facial profile when compared to non-Class III children ($P = 0.002$ and $P = 0.018$). Similar to this approach, Božic et al. [2] showed low concordance (33–38 %) between the adult Slovenian Class III faces (14 male and 15 female) and the average facial templates constructed from 43 male and 44 female Class I subjects. However, these results involved the whole facial area. They also demonstrated that in 50 % male and 60 % female Class III subjects, there is significant difference in the upper facial third.

Conclusion

In this paper, an up-to-date review of existing approaches for the construction and application of three dimensional facial averages or norms is made. Techniques and applications are categorized and analyzed, thus providing the reader with a comprehensive overview of the research field. It is found that although many approaches have been proposed with two dimensional facial data, there is only a limited number of articles available using three dimensional data and appropriate standard protocols are yet to be developed. The potential applications of 3D averages or norms and the identification and discussion of the underlying problems and challenges described in this article imply that significant further research should be performed.

Acknowledgment This research is sponsored by the Australian Society of Orthodontists Foundation of Research and Education (ASOFRE) Special Donation grants PG51311900 and PG51312000 and, by the University of Western Australia under Research Development Award (PG12104373) and Research Collaboration Grant (PG12105002).

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Reducing Stereotypes of Women in Technology Through Analysis of Videogame Blog Entries

Reva Freedman and Georgia Brown

Abstract

In this paper we analyze some of the most frequent stereotypes about women found in videogames. One way to negate these beliefs is to look at real data. Since contemporary students prefer blog entries to hardcopy or longer articles, in this paper we examine some inaccurate but widely held beliefs found in the videogame industry and analyze blog entries that can be used to negate them. This idea grew out of a mixed-gender class in game programming at Northern Illinois University in Spring 2012.

Keywords

Women in computer science • Stereotypes • Videogames • Blogging

Introduction

In this paper we analyze some of the most frequent stereotypes about women found in videogames. Since videogames are a modern technological creation, it would seem logical that authors and users of videogames would not be biased. However, that does not seem to be the case.

It is important to study these stereotypes in order to come up with ways to negate them. Defeating these stereotypes is important for the full integration of women in computer science and engineering, not necessarily because either women or men necessarily believe in these stereotypes, but because we live in a culture where these stereotypes still hold sway.

One effective way to defeat these stereotypes is to carefully examine them. Since contemporary students prefer blog entries to hardcopy or longer articles, in this paper we list some inaccurate but widely held beliefs found in the videogame industry and analyze blog entries that can be used to negate them.

The idea for this paper grew out of a mixed-gender class in game programming at Northern Illinois University in Spring 2012. The course was given under the seminar topic "Topics in Women and STEM." Although the class contained a mix of gamers and non-gamers, most of the women in the class started with little or no programming knowledge or interest. Most of them had registered for the class because they needed a course in Women's Studies and it fit their schedule. Many were scared about the programming requirement, but most of them ended up embracing the experience.

Some of the women did not know they needed to eject flash drives after use or how to unzip a file they had downloaded. Many were concerned that they would not be able to succeed in the class. However, by the end of the class, all of them had produced detailed games and each had had an opportunity to think about their abilities and interests.

During the class many aspects of women and technology were discussed. A comment made by many students was that no one in middle or high school had ever discussed computers or programming with them as a career path. Hence it seemed relevant to discuss stereotypes of women in videogames as a way of defraying their power so that these students new to computing would feel welcome in the community.

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_54,

In the first two sections of this paper, we will examine the most common stereotypes about women with regard to hardware and videogame software. Then we will look at some vicious circles caused by these stereotypes. Finally, we will look at some ethical issues involving women in videogames and draw some preliminary conclusions.

What Women Want in Hardware

Stereotypes

There are several common stereotypes about women and technology:

- Stereotype #1a. Women don't play videogames.
- Stereotype #1b: Women aren't interested in technology.
- Stereotype #1c: Women are more interested in looks than function.

In the remainder of this section, we will examine the corresponding facts.

The first stereotype is easy to dispose of: Women own more video game consoles than men, but most women aren't "hardcore" gamers, i.e., frequent players of adversarial games [1].

Stereotype: Women Want "Pink" Technology

The other two stereotypes are not true either. In fact, what women want is technology that works. According to Genevieve Bell, Intel's resident anthropologist, our society's beliefs about women in technology are out of sync with the amount of technology women own. Women want technology that works immediately and consistently so they can use it in the background of their lives [1].

In *Wired*, a popular magazine for tech enthusiasts ("geeks"), most of whom are male, Martinelli, reporting on a study of women and technology, states that "women like technology, they just don't need it to be *pink*. Ninety-one percent would prefer something sleek and sophisticated to something 'feminine'" [2]. Only 9 % of those questioned felt it was important that gadgets looked feminine. Many said that they felt patronized by "pink digital radios and diamante-encrusted mobile phones" [3]

The women in the top category in the study, which included 37 % of the total, owned an average of six devices, including digital cameras, computers, smartphones, MP3 players, TVs, and game consoles. Overall in the U.K., women own only slightly fewer tech items (11 %) than men.

That doesn't mean that today's consumer electronics stores are female-friendly: More than half the women in the study reported leaving a tech store without buying because they couldn't find what they wanted. In addition, women buy less tech equipment when store staff assume they are ignorant or uninterested [3].

Stereotypes of Women and Videogame Software

Two Interrelated Stereotypes

There are two separate but interrelated common stereotypes about women and videogame software:

- Stereotype #2a: girls prefer non-adversarial activities rather than adversarial games.
- Stereotype #2b: girls want to do things involving stereotypically female content in their games.

There is nothing wrong with either of these beliefs as long as they reflect the users' true feelings and not what they have been coerced into.

For stereotype #2a, we must consider the following options:

- Hypothesis 2a-1) On average, girls genuinely do prefer non-adversarial activities.
- Hypothesis 2a-2) Many girls are coerced into saying that they prefer non-adversarial activities by social pressure.
- Hypothesis 2a-3) Many girls do not have the option to find out what they would genuinely enjoy because marketers advertise to them as if they prefer non-adversarial activities.

  These alternatives are independent; each of them can be true or false.

  Similarly, stereotype #2b admits the following alternatives:

- Hypothesis 2b-1: On average, girls genuinely prefer games with stereotypically female content.
- Hypothesis 2b-2: Many girls are coerced into saying that they prefer games with stereotypically female content by social pressure.
- Hypothesis 2b-3: Many girls do not have the option to find out that they would genuinely enjoy because marketers advertise to them as if they prefer stereotypically female content.

Again, each of these alternatives can be validated or falsified independently.

Many problematic games support both stereotypes, although it is not clear why the two stereotypes occur together so often. For example, according to Godfrey [4], the first game young girls have access to in elementary school is "some kiddie title in which all you can do is pat the puppy and put on makeup." This type of game exemplifies the worst aspects of both stereotypes 2a and 2b.

In the next two sections we look at two corporations whose games that support both of these stereotypes in different ways.

Ubisoft

In 2007, French game publisher Ubisoft came out with a series of games for girls entitled "Imagine," whose main topics were shopping, fashion, animals and babies. The games are simple role-playing simulations with cartoon-like graphics intended for girls from 6 to 14. The Imagine series includes *Imagine: Fashion Designer*, *Imagine: Master Chef*, *Imagine: Animal Doctor*, *Imagine: Figure Skater,* and baby-sitting simulation *Imagine: Babyz (sic)*.

Taylor [5] criticized this series, objecting to the fact that "Ubisoft seem[s] to think that this is only what girls like." Recognizing that the problem is not shopping per se but girls being slotted into it, Taylor pointed out that World of Warcraft, a game which certainly appeals to young men, is at least 40 % shopping, and asked why non-shopping options aren't then available for young women. Ashcraft [6] agrees that Ubisoft is propagating female gaming stereotypes in their Imagine games.

Ubisoft claims that their in-house research showed that preteen girls are interested in things like fashion, cooking and caring for babies and animals, and they are just fulfilling their users' needs. They claim that the games were for young girls who are looking for ways to explore their hobbies: "From what we've seen, [the girls] didn't mention anything about being a police officer". Ashcraft says he can't wait for *Imagine: Glass Ceiling* [6].

JCPenney

JCPenney [7] developed an online game, Dork Dodge, whose real goal was to interest young women, especially incoming college students, in shopping there. Dorm Life is a "lifestyle brand" designed to appeal to these students. JCPenney is interested in teenagers because they view them as subject to influence and that they would buy most of their clothes and furniture in their first year. Furthermore, they assumed that these young women would use clothing and furniture as a way to express themselves and relate to other women.

Dork Dodge was part of the advertising campaign for Dorm Life. In Dork Dodge, the players' goal is to dodge "dorks," or undesirable dates. The main screen resembles Habbo, a social media site aimed at teenagers. The dorks appear on video. A pop-up menu lists possible actions. In general, the way for a user to blow off the dorks is to act passive-aggressive, such as by giving out a fake email address.

Dork Dodge clearly fulfills both stereotypes. The game authors were all women, and they based the scenarios on their own memories of being beginning college students. Elements such as the passive-aggressive actions were intended to be particularly female. That does not mean that the scenarios are inaccurate, just that the players' options for responding are limited. Several men who watched the Dork Dodge videos found themselves "fluctuating between laughter and cringing."

The creators of Dork Dodge used the same argument as Ubisoft, namely that they were just giving the users what they wanted: "To create Dork Dodge, we actually started from our young adult target's vantage point and researched insights."

Microsoft

Microsoft explicitly supports stereotype 2a but does not specifically mention 2b. In 2007 Microsoft CEO Steve Ballmer stated that Microsoft has been targeting non-video game users by targeting young women with games like Viva Piñata and older women with arcade games, board games and card games [8]. In 2011 he stated that he thinks about the Xbox as a place to socialize rather than a gaming platform and would like to see girls using the Kinect with it [9, 10].

Vicious Circles

This section shows how attitudes toward women can be intensified and propagated to the next generation due to a vicious circle.

Vicious Circle #1: Turning Girls Off with Lame Games

According to Godfrey [4], although games contain rampant sexism and guns and violence, neither of those is the primary factor that turns women off. In her mind, the main problem is that girls are forced to choose between topics of interest to girls and games that Godfrey thinks are fun, which are marketed to boys. She says: "This is where the vicious cycle begins. Publishers make games less like games and more like lame interactive experiences to market to a population that they assume dislikes games. The games produced under this model [expletive verb deleted]. Yet inevitably some of the target audience will buy the product anyway only to discover that it really is lame. The target audience, these girls, then make the fatal assumption that since this game which was supposedly more accessible to them is lame, then all games must be lame."

An anonymous commenter to Alexander's blog [11] points out a major assumption in Godfrey's thought, i.e., that everyone else may not agree with Godfrey that non-adversarial games are lame: "I'm starting to feel like the suggestion that casual games can be a gateway drug to proper gaming is a good example of a problematic attitude. It implies that the experiences of Halo and Warcraft are somehow more pure, better than Bejeweled and Diner Dash, and that once people have been tempted into trying 'real games' they'll see the light and somehow become hardcore gamers. Doesn't the fact that Bejeweled has sold more than Halo and World of Warcraft combined and appealed to a much broader audience show us that IT, in fact, is the better game? It's especially impressive when you consider that the self-proclaimed hardcore gamers are not exactly a bastion of diversity."

Vicious Circle #2: The Next Generation of Game Designers

In addition to being turned off by the lame games marketed to women, Godfrey [4] is concerned that girls don't learn the language of adversarial games, so they do not have the background to become game designers and remedy the problem for the next generation of girls. "The bigger problem behind this vicious cycle is that games have an innate and oft-exclusive language of their own; it's a language that takes some learning. The most hardcore gamers of our current generation, many of whom are going on to become game designers, have this language hardwired into their brains when they are exposed to games at early (and earlier and earlier) ages."

Vicious Circle #3: Seeing Only What You Research

Taylor [5] responds to Ubisoft's claim that they did their research and that the girls didn't mention anything about non-traditional careers. As she says, "research is a funny thing. If you say to someone, what's your favorite food, they'll list three things they love. If you then say, you didn't list chocolate cake, don't you like chocolate cake? They'll say, oh SURE! I love chocolate cake! I just didn't realize you were asking about chocolate cake."

Taylor points out that if young girls only liked these stereotypical female topics, they wouldn't like Wii Sports, Pokemon, or many other games that appeal to children of both sexes.

She finds it ironic that a series entitled Imagine has so little imagination. Ashcraft [6] also reacts ironically to this series. He suggests a game entitled "Imagine: The Glass Ceiling," and notes without comment that Ubisoft changed *Imagine: Babies* to *Imagine: Babyz*.

She would like to see more female police officers, sports referees, politicians, military people, marketing strategists, and farmers in the real world, so those occupations need to be represented in games to suggest the idea to young girls. She concludes that more female video game designers are required in order to make this happen.

JCPenney did the same thing: They did research on what young women want, but in a very shallow way.

Corporate Ethics

In this section we look at places where corporations have acted in ways that bring up ethical issues.

Games as Ads

JCPenney was clear to their interviewers that the purpose of their game is to sell merchandise. But we do not know whether they are clear to the end user, and whether it would make any difference, since the game has the nature of an "attractive nuisance."

Targeting Girls

Jana [12] says that advertising non-adversarial games only to girls is both socially and economically short-sighted. In addition to missing half the market, she thinks it would benefit everyone to market these games to boys for teaching problem-solving, resource-management, and hand-eye coordination skills, or simply as an alternative to adversarial games.

Sexism in Games

Taylor [5] describes advertising of videogames marketed to boys as similar to that for girls "except it was a bit more gory, and featured far more guns and boobs."

Although women own more videogame consoles than men, most women are not hardcore gamers. Some experts say that the problem is the industry only presents female characters from a male point of view.

Floyd and Alexander [13] point out that there is a difference between adding more female characters and just adding additional characters for the benefit of men. Even when female characters are strong and competent, such as Lara Croft, they are often marketed for their looks.

Most characters, both male and female, have extremely attractive avatars because no one wants to be "an uglier, weaker version of themselves." But while a male character's sex appeal is never stressed in the game's advertising, a woman's always is, generally to the exclusion of everything else about her. In addition, women's bodies are often exposed during the game.

Individual Ethics

In this section we look at ways in which the actions of individuals cause problems for female game players.

Harassment of Female Gamers

According to Kral [14], people often play as opposite-gender characters. Sometimes it's to explore what it's like to be a member of the other gender, but sometimes men just want to use hyper-sexualized female characters like Lara Croft as their avatar as a form of eye candy. On the other hand, women are sometimes driven to play as a male character to avoid discrimination during online game play. Some don't want to be branded as incompetent and others do it to avoid harassment [15].

Ignoring Women's Needs

Alexander [16] originally did not want to be considered a "woman in games", but rather a "person writing about games who is, among other things, female." She did not want to present "a women's perspective" even though that is often what others wanted from her. However, she is coming to see that just doing her best work has not been leading to change in the field, so she has become more interested in talking about female-specific issues. Similarly, she has also been moving from a neutral role toward an advocacy position.

Related Work

Books [17] and [18] resulted from two iterations of a conference and include many articles on women in videogames. Book [19] discusses how to develop gender-neutral games.

Alexander was a guest on the Digital Cowboys podcast, episode #111 [20], discussing how female characters are represented inside video games.

Conclusions

Economic and Social Consequences

Video game companies have developed an interest in attracting more women but they haven't figured out a way to bring a large number of women into the subgroup of intense adversarial gamers who are interested in buying a large number of games [21].

Floyd [13] concludes that the industry needs to stop putting forth a message that makes women think that "this is not for you." He says: "As an industry, we need to seriously reconsider our marketing. We need to examine our habit of manipulatively using women for appeal – 'booth babes' at our conventions, exploitive character design. We need to consider the effect this stuff has on our industry's image."

Aside from just hiring more female video game designers and executives, he states that one way to change the industry is to stop marketing games specifically to one gender and find the happy medium between "games featuring bloody cage fights and babies."

This short statement summarizes what is necessary to negate both stereotypes 2a and 2b as well as vicious circle #2 and the corporate ethical issues of sexism and targeting girls. Of course, it presupposes that getting more women involved in adversarial games is a good thing.

The Possibility of Different Male and Female "Rhythms"

One possible change to adversarial games that might make them attractive to more women is suggested by Godfrey [4]. She believes that men and women have different game-playing rhythms and that the current game language caters to male rhythms. In her opinion, the mechanics of a game lead the player alternately through periods of stress and relaxation, and women respond differently to stress than men. While men under stress tend to leap into a fight-or-flight state, women tend to look to social strategies. Given a specific enemy, boys will tend to engage in physical fights and then cool off rapidly, while girls will plot long-term social strategies.

In her opinion, creators of adversarial games can target girls by ensuring that interactions between characters have solid consequences and are not just sentimental use of emotions. Instead of the quick bursts of intense action followed by cut scenes or load screens, they should draw the game out and give the player time to strategize, while also permitting the opportunity to go in for the kill at a moment's notice.

Taylor [5] does not agree with the idea of different rhythms and no other commentators consider it.

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Improving Student Learning While Converting a Computer Architecture Course to Online Format

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Abstract

A required Computer Architecture course for Computer Science majors was converted to online form in Spring 2011. In this paper we discuss the changes made to make the course successful online, especially in content preparation, course organization, and the construction and handling of assignments. We discuss why we feel the revised course produces improved student learning in terms of the basic principles of scaffolding, self-explanation and multimodal learning. We also discuss how we made the course practical to administer on an ongoing basis. We hope that this experience will be helpful to other faculty members planning to convert courses in Computer Science or Engineering to an online format.

Keywords

Online education • Computer science education • Teaching computer architecture

Introduction

In this paper we discuss the conversion of a Computer Architecture course to online format and how those changes led to enhanced student learning. The course is a standard introduction to computer architecture taught in a Computer Science department for software-oriented students.

Since much of the material is descriptive and there is no laboratory available for this class, this course seemed like a good fit for online development. We expected the revised course to be an enhancement for students with time conflicts: non-traditional students with work or family obligations, students doing internships, and students with long commutes to our exurban location.

In this paper we discuss the three basic principles that we used in redeveloping this course. Then we discuss changes made to each area of the course, including content preparation, course organization, assignment preparation, assessment and course delivery, and show how these changes are aligned with the three basic principles. Additionally, we show how each of these items was optimized to make the course practical to administer on a regular basis. We conclude with some reflections on improvements caused by the conversion, potential future improvements and a couple of caveats.

Pedagogical Principles

We were guided by three basic principles in redeveloping this course.

1. Scaffolding. In problem solving, scaffolding refers to helping students satisfactorily solve a problem by breaking the problem down into smaller steps that they can satisfactorily complete [1]. Scaffolding is used to aid students in both the conceptual and procedural learning required in the course. For some of the more difficult concepts, the assignments contain questions forcing the students to think through the meaning of diagrams in the PowerPoint slides and their consequences. With regard to procedural learning, where the majority of uses of scaffolding in this course are located, the sample problems

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_55,

are divided into steps, and the problems that students are given in the assignments are divided into equivalent steps.

2. Self-explanation. According to the theory of self-explanation in problem solving [2], students learn by studying examples of solved problems and explaining to themselves how the solution worked. In our online course, for each type of problem that students are expected to solve in the assignments, a worked example is provided either in the PowerPoint slides or in a standalone file.
3. Multimodal learning. In Fleming's controversial theory of learning styles [3], students learn via visual, auditory or kinesthetic modalities, or a combination of them. Without judging whether this theory has been scientifically proven, as a rule of thumb, I have found it useful to make sure that each major concept is taught in all three ways. In the online course, every major concept is shown on one or more PowerPoint slides, covered in the corresponding audio lecture, and reprised in homework that students do themselves.

The following sections of the paper discuss the content organization and assignments. The influence of these principles can be seen in multiple places in these topics.

Content Preparation and Organization

Format of the Online Course

In our department, as in the university as a whole, there is a wide variation in the media used in online courses. Many faculty in the humanities use only uploaded text plus a discussion group. In the Computer Science department, formats vary from text-only to video. For this course I chose to approximate what I would do in a face-to-face class by using PowerPoint slides with full audio lectures for each set of slides. I did not use an integrated video setup because I wanted the flexibility to be able to update content and fix errors quickly. Although I expected that most of the problems would be in the audio portion, that expectation was not borne out. In fact, there have been very few errors that needed correcting, and most were typos that did not require updating the audio. Still, it was easy to edit the audio to add additional explanations and scaffolding where required.

In general, our department requires that students come to campus as a group for the exams. Most of our online classes also have one introductory meeting to make the course more real to the students. In addition to meeting the instructor, I always arrange for them to meet the teaching assistant at that time.

Content Selection

The face-to-face version of this course contained two 75-min lectures per week. Of the 29 class meetings, 2 were dedicated to exams. The 27 class meetings were divided into 3 sections of 9 lectures each. Each section was divided into 3 topics of 3 lectures each, with a lengthy homework assignment for each topic. On average, about one third of this time, i.e., the equivalent of one class period, was used for discussing the assignments and interacting with students. In addition to answering questions in class, this time included explaining each assignment, answering questions about it, and reviewing it after grading. Therefore approximately two class periods, or 150 min, were available for actual lecture material for each topic.

However, on an empirical basis, 150 min per topic is too much for the online course, possibly because the act of listening to a recording is more intense. Students need to repeat parts of the recording to truly understand some of the more difficult topics. Therefore we have tried to keep the amount of recorded material to approximately 90 min per week. That allows for 15 min of concentrated listening per day with one day off per week.

In fact, in the face-to-face class the instructor did not need all of the class time to cover the material stipulated in the syllabus. In this manner the online course is more flexible and respectful of students' time, since it is not considered acceptable to dismiss the students early in a face-to-face class. For the better-prepared students, the online class is thus more respectful of their time.

In a few places we deleted material that turned out to be review for the majority of students. Again, we learned empirically what was not required. Students needing the deleted material can find it in their textbook, in their notes for the earlier course where it was covered, or online. This material has included a review of the binary number system which students are expected to have learned in a previous course. We kept the material on two's complement although students have studied it in an earlier course because many students still do not understand that all numbers, positive and negative, have a two's complement representation. We are currently doing a survey to see if we can delete the introduction to Boolean logic. This material currently occupies one of the assignment slots that we would like to use for other material.

Some material that was not deleted on our initial review was deleted in a subsequent semester. These topics included theoretical material on number bases other than powers of 2, historical material on obsolete hardware, and material on variable-length opcodes that students can figure out for themselves if needed. We would like to have deleted the material on one's complement, which is not needed in itself, but it turned out to be the easiest way to introduce the important topic of two's complement.

Slides as Core of Content Organization

Although we originally believed that the slides from the publisher would stand on their own, many of them had to be redone. The course was designed using the second edition of the textbook [4]. For new topics, I have used the slides from the third edition [5]. Regrettably, most of the problems described below were not corrected in the third edition.

The two main issues were typographical issues and missing content. In addition, the slides had to be divided into smaller sections for the convenience of both students and instructor. Details of these three types of changes are included below.

Typographical Improvements

1. Assigning permanent slide numbers. The publisher slides used only the default PowerPoint numbering. In a face-to-face class, students can ask about a problem when they see it. But in an online class, permanent slide numbers are required for students to ask via email. The permanent slide numbers also turned out to be very useful for faculty, as in addition to email, I frequently referred to specific slide numbers in the assignments, e.g., to point to an example or diagram.
2. Correcting formatting errors. The text of the publisher slides were inconsistent with regard to font, font size, and spacing. The text boxes were inconsistent with regard to placement on the page. In addition, some text boxes overran one or more of the page margins. Overlapping objects, such as a diagram overlapping part of a text box, made it hard to edit slides and caused problems when changing font sizes. These issues had not caused problems in the face-to-face class because in the latter I only used slides to show diagrams.
3. Providing more specific headings. The publisher slides had only one title for each section of the book, regardless of how many topics were covered in that section.
4. Removing superfluous words. Many of the publisher slides contained unnecessary verbiage. Removing this had two advantages: it made the slides easier to read and increased the probability that the text would still fit when the font size was corrected.
5. Numbering the examples. This change had two advantages: in addition to making the examples easier to refer to, it increased the salience of the examples in students' minds.
6. Cleaning up examples. Sometimes one example was continued through several slides with interpolated text referring to the general topic. To make the slides useful for self-study, it was more useful to have complete examples that I could refer to on the recordings.
7. Repeating diagrams. When a diagram was referred to on several consecutive slides, I tried to repeat the diagram on each slide so that students would not have to flip back and forth. Although effective, this also has the negative side effect of making the material look like it contains more complex diagrams than it does.

All of these changes were in service of making it easier for students to recognize what material they needed to self-explain.

Filling Out Content

I expected to have to delete slides for content I considered secondary or unnecessary. However, I was surprised that few to no slides were provided for several important topics. For other topics, the slides could not stand on their own without extensive additions. In addition, for other key topics, some definitions were provided but no complete worked examples. In particular, our goal was to provide a worked example for each type of problem found in the assignments.

File Processing

The publisher provided one file per chapter, regardless of how long it was. I divided the slides into sections by topic, averaging about six sections per chapter. Norvig [6] divides his slides into much smaller divisions so that his average section contains only ten minutes of recorded text. He finds that ideal for enabling students to listen carefully to an entire section at one sitting. I found 20–25 min to be a good compromise. Students found sections over 30 min inconvenient, but having too many sections made it inconvenient to keep track of them on Blackboard and in my files.

Audio Recordings

I made the recordings using a simple noise-cancelling microphone, purchased online for about $20. I used Audacity, which is free, open source and easy to use. For the first few recordings, I paused frequently to slow down content delivery to what I estimated would happen in a face-to-face class. However, in a face-to-face class this is natural due to watching students' facial expressions. Students told me that the recordings sounded odd due to the extra pauses, so I stopped doing that and have received no complaints that the recordings go too fast.

Overall, the time to record a given section is approximately twice the final length. This time includes making sure that all the materials are available, stopping when tired, and correcting errors. On average, my speaking speed is for these recordings is about the same as for research presentations. For me, that works out to one slide per minute.

Course Web Page

Finally, I maintained one master web page containing a list of slide sections. Along with each section title, the number of slides and length of the audio recording was included. The slide sections were organized by chapter. Due dates for the assignments and the dates of the exams were inserted at the appropriate points.

I found this web page to be an indispensable resource in ensuring that each week had an appropriate amount of content and homework problems. However, students rarely referred to it, preferring to obtain their information about the progress of the class from the weekly Blackboard announcements. Students informed me early on that they preferred to obtain all of their information from Blackboard rather than having to go directly to the web for some items. I kept the master web page on my web site so I could refer to it easily, but posted a pointer on Blackboard for student convenience. The only other file I maintained on my web site was the course syllabus.

Review Sheets

I provide review sheets just as in the face-to-face section. The review sheets are more important in the online section because students don't have non-verbal cues from the professor as to what is core material as opposed to interest-provoking ideas, background material, or additional detail which is useful for setting a context but not itself important.

Assignments

Content Selection for the Assignments

More assignments are needed than in an in-person class for three reasons: first, because the instructor has no other way to know whether students have understood the material; second, because more scaffolding is needed in multi-step problems; and third, because scaffolding is needed to make sure students are self-explaining the material in the slides.

Our goal was to make each question in every assignment easy both to submit and to grade. We converted everything to short-answer questions. Most questions had a numeric or other short answer; a few asked for a one-sentence explanation. In the latter case, the teaching assistant was instructed to accept any wording that was conceivably correct, since more students understood than could put their understanding into words.

For each assignment, an assignment sheet and an answer form were posted on Blackboard. Each question was divided into parts that could be answered as explained above. The questions were numbered and the parts within each question were labeled 1a, 1b, etc. The answer form, which was an Excel spreadsheet, contained a blank line between questions.

The questions were grouped by topic so that students could see that every homework question was related to a topic in the course. Except for questions whose goal was to make sure that students did the reading, an example was provided in the slides for each section. Where that was not practical, the example was provided separately. Where necessary, the slide number or filename of the example was mentioned on the assignment sheet and/or in the Blackboard announcement introducing the assignment.

The number of points for each question was preloaded in the leftmost column of the spreadsheet, with a formula for the total in the top row. This greatly increased the efficiency of grading since the teaching assistant only had to change the score when an answer was incorrect, and did not have to type anything when the answer was correct. For most questions, the parts were small enough (average 2 points) that it was not necessary to give partial credit, also increasing efficiency. In addition, it was not necessary to write in the correct answer because complete answers were posted online once the graded homework had been returned.

Finally, space was left at the top of each spreadsheet for the student's name and university ID. This is important because that information is not necessarily visible from Blackboard while looking at the spreadsheet.

Students can use any spreadsheet program to do the assignments. They are instructed not to change the file format or the format of the answer form. In general, this has not been a problem for either students or the instructor.

Grading

After grading each spreadsheet, the teaching assistant attaches the graded version via Blackboard so that students could see which questions they had lost points for.

Converting each question to a scaffolded form and drawing up the spreadsheets was time-consuming in the beginning, but after a few iterations of the course to tune any confusing questions, we have been able to reuse the spreadsheets.

Our department strongly believes in providing sufficient office hours to handle the needs of students. As a result, they did not increase the class size when the course was converted to online form. However, this situation could change in the case of financial exigency. Another advantage of this approach to grading is that it would be possible to write a program to grade the majority of the questions automatically. Although Blackboard's grading is not flexible enough for the binary, hex, floating point and other formats used in this course, it would be straightforward to grade most of the questions mechanically.

Analysis of Graded Assignments

In addition to feedback to the students, the T.A. also prepares a summary sheet created by copying the grade column of each student's spreadsheet into one sheet. This summary sheet thus contains a matrix showing student grades for each question. These summary sheets receive detailed analysis as a way to find out how the course is doing on a question-by-question basis. I also occasionally receive emails from the T.A. noting problems with particular topics that he has noticed from grading or from talking to students. In general, the T.A.'s intuition matches what I have learned from analyzing the weekly spreadsheet.

I experimented with asking the T.A. to provide a second spreadsheet containing the actual answers to each question for each student. Although that seems superficially similar, it turns out to be much more work for the T.A. due to the varying length and format of the answers. Therefore, although the results would be useful for research, I no longer require that. The T.A. sends me a weekly file containing all of the student spreadsheets, so that data is available for analysis.

Learning specifically which questions or parts of questions students had trouble with has multiple benefits. In addition to improving the presentation of the topic for the following year, I can send out additional explanatory material or add new questions to a following assignment in addition to making sure the problem areas are emphasized on the exam review sheet. It is also possible to do equivalent analysis on the exam questions to make sure the issue has been remediated.

Posting Answers on Scribd

The first time I taught the online version of the course I tried to avoid posting the answers by having the teaching assistant type in the correct answers for students. However, this was not satisfactory because it was impossible to be completely accurate and provide alternative solutions.

We are now using Scribd to post the answers. Although Scribd defaults to public datasets, it is straightforward to change the files to private use. At the same time, I change the Scribd options so that students cannot copy, download or print the answers. After each assignment has been returned to the students, I post the Scribd URL, which contains a password, in a Blackboard announcement. Although there is a small inconvenience in not being able to download or print the answers, this is overridden by the fact that students cannot set up an answer file for future semesters. Although I change the assignments every semester, there is no question that students with access to an answer file still have an unfair advantage.

I send the teaching assistant a copy of the answer form with the answers filled in so that he or she can line it up with student work and grade it easily. I tell students that the teaching assistant and I have this form so that if the Scribd answers are too difficult to read, they are welcome to come and study our copy. I rarely have a taker on this, as Computer Science students are used to using online services. To make the Scribd version easier to read online, I occasionally have to reformat the answer sheet so that the number of columns fits on one landscape page. In general this just means putting a few of the longer answers on two lines instead of one long line and similar simple changes. Scribd provides a count of the number of readers; many but not all students check out the answers.

To the best of my knowledge, none of the students has been able to break the Scribd encryption. In fact, I have had very little cheating in this class compared to, for example, our basic programming classes. I believe this is because the material is well-organized and students know exactly what is required to get a good grade. Due to the spreadsheet organization, it would be a simple matter to do automated comparison on the homework if cheating was suspected.

Regrettably, there is no simple equivalent of Scribd for posting answers to the exams. I encourage students to come to my office to see their graded exams, but they rarely do. There is a learning opportunity lost here.

Course Delivery

I post approximately four announcements per week to Blackboard. One is the regular weekly announcement listing the topic for the week, occasionally with some background or encouragement. If the assignment is not posted at the same time, I post another announcement for it. Other announcements are for corrections, clarifications, or departmental announcements. Students prefer Blackboard announcements to email because they receive so much unsolicited university email.

Assignments are due at the end of the day on Thursday. Students receive 10 points extra for turning them in a day early. Since most assignments have less than 100 points, this is a significant advantage. Students who turn the assignment in early every week can raise their final grade by one-half grade. Approximately one half of the students take advantage of this every week, often but not always the same students. There is a 10 % deduction for being up to one day late, and that is the final deadline. Only a few students need the late day; thinking about the early deadline apparently helps more students get the assignment in on time, if not early.

If all of the materials are ready, it still takes up to an hour to post everything on Blackboard, including links to the readings, the assessment, and the directory where the assignments are stored.

Email

Email is important for identifying student problems since facial expressions are not available. Quick turnaround is important for relationship maintenance [7] as well as for helping students meet their deadlines. Since students taking this class are upper-division Computer Science majors, the volume of email has not been a problem.

Conclusions

Improvements over the Original Face-to-Face Version

As suggested by Piña [8], converting the course to an online format forced us to be more explicit about the pedagogical principles involved and the content to be covered. It also required us to be more explicit about the scaffolding in the assignments and the scheduling of readings, assignments and exams. A side effect of planning for the online format was a better mapping between lecture, homework and exams. Although other people have reported higher dropout rates in online classes, I have had no failures and minimal dropouts since converting this course to an online format. In addition, I have received compliments from students for using their time more efficiently. It is of course possible that after several semesters of experience with the online class, students are to a certain degree self-selecting to take this course as opposed to a face-to-face section.

Potential Addition of Interactive Online Materials

Piña [8] suggests that online classes should include interactive practice problems for every topic. This could be accomplished using interactive PowerPoint features, as is frequently suggested, but it could also be done separately as part of a game or interactive tutorial system [9].

The rationale for this suggestion is that in addition to increasing student engagement, the role of homework is to prepare students for the exams. But since homework counts as part of their grade, students would benefit from a non-graded opportunity to practice their skills before doing the homework. Since these features are time-consuming to develop, it would make sense to do a prototype feature and evaluate it to see if it increased student engagement and/or understanding of the selected topic.

Two potential downsides of this enhancement are the risk of being incompatible with the variety of software and platforms students use to study the course slides, and the risk of wasting time for the better-prepared students. It should also be noted that according to the exams, students do learn the material, and the face-to-face version of this course did not in general have much student involvement in spite of the best efforts of the instructor.

Disadvantages of Added Scaffolding

Students learn what they practice. Students complain when the scaffolding in the assignments does not match the scaffolding in the slides. In addition, the exam questions are broken down into parts for easier grading and fairer assignment of partial credit. Students often assume that those intermediate questions are in the same sequence and contain the same content as the scaffolding of the assignment questions. Whether this is a problem depends on the depth of understanding of each topic that students will need in the future. This problem was most acute in the sections on change of units, the bitwise binary calculations needed for direct caching, and floating point calculations. It is especially surprising that change of units was a large problem resistant to multiple attempts to teach it.

Summary

In this paper we described the basic principles of scaffolding, self-explanation and multimodal learning that guided the transformation of a Computer Architecture class from face-to-face to online. Changes were made in course content and organization, assignments, and course delivery to follow these principles as well as to make the course easier to administer online. We showed how the revised course met the needs of some students better than the original. In addition, it met the scheduling needs of non-traditional students and others with full schedules.

This course was chosen because it had a large amount of descriptive material and minimal programming. It also contained a moderate amount of problem solving. It remains to be seen how the results would generalize to a course with a larger quantity of programming or algorithm development.

Positive aspects of the course development included a decrease in the number of students having to repeat the course and a general lack of complaints compared to the original class. However, like other online courses, developing the course was a time-intensive activity that must be amortized over several semesters. Running the course involves approximately the same amount of time as the face-to-face course but the time requirements are more flexible, i.e., it is a time-shifting rather than a time-saving activity.

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Bioclimatic Modelling: A Machine Learning Perspective

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Abstract

Many machine learning (ML) approaches are widely used to generate bioclimatic models for prediction of geographic range of organism as a function of climate. Applications such as prediction of range shift in organism, range of invasive species influenced by climate change are important parameters in understanding the impact of climate change. However, success of machine learning-based approaches depends on a number of factors. While it can be safely said that no particular ML technique can be effective in all applications and success of a technique is predominantly dependent on the application or the type of the problem, it is useful to understand their behaviour to ensure informed choice of techniques. This paper presents a comprehensive review of machine learning-based bioclimatic model generation and analyses the factors influencing success of such models. Considering the wide use of statistical techniques, in our discussion we also include conventional statistical techniques used in bioclimatic modelling.

Keywords

Machine learning • Bioclimatic modelling • Geographic range • Artificial neural network • Genetic algorithm • Evolutionary algorithm • Classification and regression tree

Introduction

Understanding species' geographic range has become all the more important with concerns over global climatic changes and possible consequential range shifts, spread of invasive species and impact on endangered species [68]. The key methods used to study geographic range are bioclimatic models, alternatively known as envelope models [38], climate response surface models [34], ecological niche models [66] or species distribution models [41]. Predictive ability lies at the core of such methods as it is the ultimate goal of ecology [63].

Machine Learning (ML) as a research discipline has roots in Artificial Intelligence and Statistics and the ML techniques focus on extracting knowledge from datasets [51]. This knowledge is represented in the form of a model which provides description of the given data and allows predictions for new data. This predictive ability makes ML a worthy candidate for bioclimatic modelling. Many ML algorithms are showing promising results in bioclimatic modelling including modelling and prediction of species distribution [20]. There are diverse applications of ML algorithms in ecology. They range from experimenting biogeographical, ecological, and also evolutionary hypotheses to modelling species distributions for conservation, management and future planning [13, 21, 22, 59, 61, 71]. In the context of Eco-informatics [27] machine learning (ML) is a fast growing area which is concerned with finding patterns in complex, often nonlinear and noisy data and generating predictive models of relatively high accuracy. The increase in use of the ML techniques in ecological modelling in recent years is justified by the fact that this ability to produce predictive models of high accuracy does not involve the

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_56,

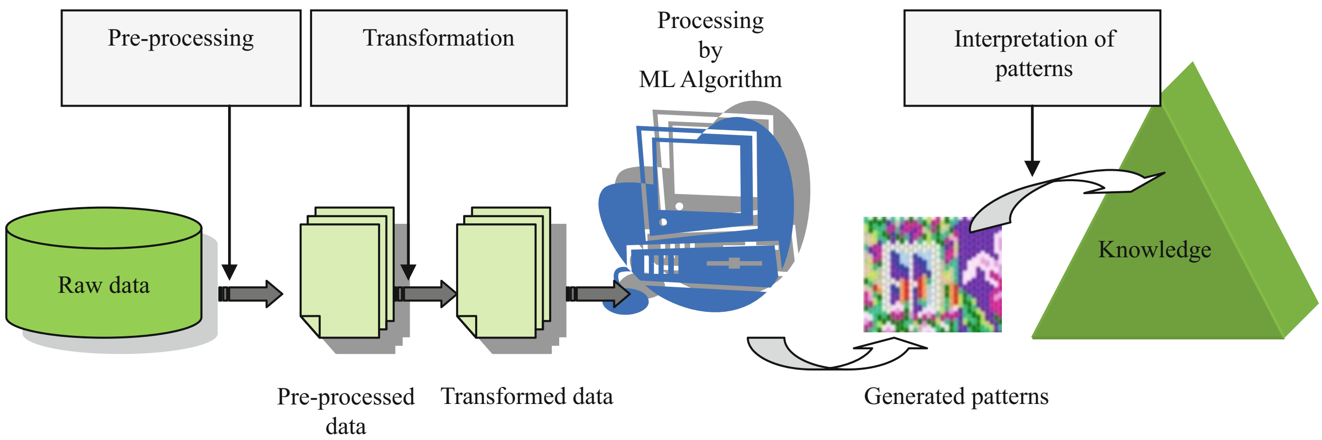

Fig. 1 Steps involved in the machine learning inference process

restrictive assumptions required by conventional, parametric approaches [20, 29, 54, 66].

It may be noted that there is no universally best ML method; choice of a particular method or a combination of such methods is largely dependent on the particular application and requires human intervention to decide about the suitability of a method. However, concrete understanding of their behavior while applied to bioclimatic modelling can assist selection of appropriate ML technique for specific bioclimatic modelling applications.

In this paper we present a concise review of application of machine learning approaches to bioclimatic modelling and attempt to identify the factors that influence success or failure of such applications. In our discussion we have also included popular applications of statistical techniques to bioclimatic modelling.

The rest of the paper is organized as follows: second section provides an overview of the Machine Learning and statistical methods commonly used in bioclimatic modelling and their applications to bioclimatic modelling; third section presents an investigation on factors which influence success of such applications; finally in fourth section, we present some concluding remarks.

ML and Statistical Techniques and Their Application to Bioclimatic Modelling

The inference mechanisms employed by Machine Learning (ML) techniques involve drawing conclusions from a set of examples. Supervised learning is one of the key ML inference mechanisms and is of particular interest in prediction of geographic ranges. In supervised learning the information about the problem being modeled is presented by datasets comprising input and desired output pairs [51]. The ML inference mechanism extracts knowledge representation from these examples to predict outputs for new inputs. The ML inference mechanism is depicted in Fig. 1.

The relatively more popular bioclimatic modelling applications of statistical and machine learning techniques and features of the relevant techniques are discussed next.

Statistical Approaches

Generalised Linear Model (GLM)

Generalised linear models (GLM) [46] are probably the most commonly used statistical methods in the bioclimatic modelling community and have proven ability to predict current species distribution [7].

Generalised linear model (GLM) is a flexible generalization of regular linear regression. In GLM the response variable is normally modeled as a linear function of the independent variables. The degree of the variance of each measurement is a function of its predicted value.

Logistic regression analysis has been widely used in many disciplines including medical, social and biological sciences [33]. Its bioclimatic modelling application is relatively straightforward where a binary response variable is regressed against a set of climate variables as independent variables.

Generalised Additive Model (GAM)

Considering the limitations of Generalised Linear Models in capturing complex response curves, application of Generalised Additive Models is being proposed for species suitability modelling [5, 6, 78].

The Generalised Additive Model (GAM) blends the properties of the Generalised Linear Models and Additive models [25]. GAM is based on non-parametric regression and unlike GLM does not impose the assumption that the data supports a particular functional form (normally linear).

Here the response variable is the additive combination of the independent variables' functions. However, transparency and interpretability are compromised to accommodate this greater flexibility.

GAM can be used to estimate a non-constant species' response function, where the function depends on the location of the independent variables in the environmental space.

Climate Envelope Techniques

There are a number of specialized statistics-based tools developed for the purpose of bioclimatic modelling. Climate envelope techniques such as ANUCLAM, BIOCLIM, DOMAIN, FEM and HABITAT are popular and specialized bioclimatic modelling tools and thus deserve mention here. These tools usually fit a minimal envelope in a multidimensional climate space. Also, they use presence-only data instead of presence-absence data. This is highly beneficial as many data sets contain presence-only data.

Other statistical methods gaining popularity includes the Multivariate Adaptive Regression Splines [19].

Machine Learning Approaches

Evolutionary Algorithms (EA)

Evolutionary Algorithms are basically stochastic and iterative optimisation techniques with metaphor in natural evolution and biological sexual reproduction [26, 32]. Over the years several algorithms have been developed which fall in this category; some of the more popular ones being Genetic Algorithm, Evolutionary Programming, Genetic Programming, Evolution Strategy, Differential Evolution and so on. The most popular and extensive application of Evolutionary Algorithm and more specifically Genetic Algorithm (GA) to bioclimatic modelling has been through the software Genetic Algorithm for Rule-set Production (GARP) [4, 66, 67]. Here, we shall restrict our discussion on application of Evolutionary Algorithm to bioclimatic modelling primarily to GARP.

Genetic Algorithm for Rule Set Production [81] is a specialised software based on Genetic Algorithm [51] for ecological niche modelling. The GARP model is represented by a set of mathematical rules based on environmental conditions. Each set of rules is an individual in the GA population. These rule sets are evolved through GA iterations. The model predicts presence of a species if all rules are satisfied for a specific environmental condition. The four sets of rules which are possible are: atomic, logistic regression, bio-climatic envelope and negated bio-climatic envelope [42].

GARP is essentially a non-deterministic approach that produces Boolean responses (presence/absence) for each environmental condition. As in case of the climate envelope techniques, GARP also does not require presence/absence data and can handle presence-only data. However, as the "learning" in GARP is based on optimisation of a combination of several types of models and not of one particular type of model, ecological interpretability may be difficult.

Examples of applications of GARP for bioclimatic modelling include: the habitat suitability modelling of threatened species [3] and that of invasive species [17, 65, 66], and the geography of disease transmission [64].

Other applications of Genetic Algorithm to ecological modelling include: modelling of the distribution of cutthroat and rainbow trout as a function of stream habitat characteristics in the Pacific Northwest of the USA [14] and modelling of plant species distributions as a function of both climate and land use variables [82]. McKay [47] used Genetic Programming (GP) to develop spatial models for marsupial density. Chen et al. [11] used GP to analyse fish stock-recruitment relationship, and Muttil and Lee [52] used this technique to model nuisance algal blooms in coastal ecosystems. Newer approaches to use Evolutionary Algorithms for ecological niche modelling are being proposed such as the WhyWhere algorithm advocated by Stockwell [80]. EC has also been applied in conservation planning for biodiversity [75].

Artificial Neural Network (ANN)

A relatively later introduction to species distribution modelling is that of the Artificial Neural Network (ANN) [43, 57, 67, 83].

Artificial Neural Networks are computational techniques with metaphor in the structure, processing mechanism and learning ability of the brain [30]. The processing units in ANN simulate biological neurons and are known as nodes. These artificial neurons or nodes are organised in one or more layers. Simulating the biological synapses, each node is connected to one or more nodes through weighted connections. These weights are adjusted to acquire and store knowledge about data. There are many algorithms available to train the ANN.

Some of the noteworthy applications of ANN are as follows: species distribution modelling [45, 53], species diversity modelling [10, 28, 56], community composition modelling [55], aquatic primary and secondary production modelling [48, 76], species classification in appropriate taxonomic groups using multi-locus genotypes [12], modelling of wildlife damage to farmlands [79], assessment of potential impacts of climate change on distribution of tree species in Europe [83], invasive species modelling [87], and pest management [90]. Please see Olden et al. [58] for further details.

The main advantages of ANNs are that they are robust, perform well with noisy data and can represent both linear and non-linear functions of different forms and complexity levels. Their ability to handle non-linear responses to environmental variables is an advantage. However, they are less transparent and difficult to interpret. Inability to identify the relative importance and effect of the individual environmental variables is a limitation [83].

Decision Trees (DT)

Decision Trees have also found numerous applications in bioclimatic modelling. Decision Trees represent the knowledge extracted from data in a recursive, hierarchical structure comprising of nodes and branches [69]. Each internal node represents an input variable or attribute. They are associated with a test or decision rule relevant to data classification. Each leaf node represents a classification or a decision i.e. the value of the target variable conditional to the value of the input variables represented by the root to leaf path. Predictions derived from a Decision Tree generally involve determination of a series of 'if-then-else' conditions [8].

The two main types of Decision Trees used for predictions are: Classification Tree analysis and Regression Tree Analysis. The term Classification and Regression Tree (CART) analysis is the umbrella term used to refer to both Classification Tree analysis and Regression Tree analysis [8].

Some of the relevant and relatively recent applications of Decision Trees are as follows: habitat models for tortoise species [2], and endangered crayfishes [86]; quantification of the relationship between frequency and severity of forest fires and landscape structure by Rollins et al. [73]; prediction of fish species invasions in the Laurentian Great Lakes by Mercado-Silva et al. [49]; species distribution modelling of bottlenose dolphin [84]; development of models to assess the vulnerability of the landscape to tsunami damage [35]. Olden et al. [58] provides a more complete list.

The obvious advantage of the Decision Trees is that the ecological interpretability of the results derived from them is simple. Also there is no assumed functional relationship between the environmental variables and species suitability [15, 74, 89]. Despite their ease of interpretability, Decision Trees may suffer from over-fitting [8, 83].

Some relevant characteristics of different ML techniques are depicted in Table 1. Also see [58].

Factors Influencing Success of ML Approaches to Bioclimatic Modelling

While it is not that straightforward to identify the causes of success or failure of applications of the Machine Learning techniques to bioclimatic modeling, in this section we attempt to outline some of the factors which may impact their performance broadly. However, this is not to undermine the fact that success or failure of any machine learning application is predominantly dependent on the specific application.

Very Large Data Sets

Data sets with hundreds of fields and tables and millions of records are commonplace and may pose challenge to the ML processors. However, enhanced algorithms, effective sampling, approximation and massively parallel processing offer solution to this problem.

High Dimensionality

Many bioclimatic modeling problems may require a large number of attributes to define the problem. Machine learning algorithms struggle when they are to deal with not just large data sets with millions of records, but with a large number of fields or attributes, increasing the dimensionality of the problem. A high dimensional data set poses challenges by increasing the search space for model induction. This also increases the chances of the ML algorithm finding invalid patterns. Solution to this problem includes reducing dimensionality and using prior knowledge to identify irrelevant attributes.

Over-Fitting

Over-fitting occurs when the algorithm can model not only the valid patterns in the data but also any noise specific to the data set. This leads to poor performance as it can exaggerate

Table 1 Comparison of some of the relevant characteristics of ML techniques

Characteristic	GLM	DT	ANN	EA
Mixed data handling ability	Low	High	Low	Moderate
Outlier handling ability	Low	Moderate	Moderate	Moderate
Non-linear relationship modelling	Low	Moderate	High	High
Transparency of modelling process	High	Moderate	Low	Low
Predictive ability	Low	Moderate	High	High

minor fluctuations in the data. Decision Tress and also some of the Artificial Neural Networks may suffer from over-fitting. Cross-validation and regularization are some of the possible solutions to this problem.

Dynamic Environment

Rapidly changing or dynamic data makes it hard to discover patterns as previously discovered patterns may become invalid. Values of the defining variables may become unstable. Incremental methods that are capable of updating the patterns and identifying the patterns of changes hold the solution.

Noisy and Missing Data

This problem is not uncommon in ecological data sets. Data smoothing techniques may be used for noisy data. Statistical strategies to identify hidden variables and dependencies may also be used.

Complex Dependencies Among Attributes

The traditional Machine Learning techniques are not necessarily geared to handle complex dependencies among the attributes. Techniques which are capable of deriving dependencies between variables have also been experimented in the context of data mining [16, 18].

Interpretability of the Generated Patterns

Ecological interpretability of the generated patterns is a major issue in many of the ML applications to bioclimatic modeling. Applications of Evolutionary Algorithm and Artificial Neural Networks may suffer from poor interpretability. Decision Trees on the other hand scores high in terms of interpretability.

Other influencing factors, which are not directly related to the characteristic of Machine Learning techniques, are as below.

Choice of Test and Training Data

Various reported applications of ML used the following three different means to choose test and training data: *resubstitution*—the same data set is used for both training and testing; *data splitting*—the data set is split into a training set and a test set; *independent validation*—the model is fitted with a data set independent of the test data set. Naturally, independent validation is the preferred method in most cases, followed by data splitting and then re-substitution. The results obtained by data splitting and re-substitution may be overly optimistic due to over-fitting [36]. However, the choice of one technique over the other is also problem dependent. Only a small segment of the reported studies seems to use independent validation.

Model Evaluation Metrics

The measure of model performance or the model evaluation technique should ideally be chosen based on the purpose of the study or the modeling exercise. It is thus perfectly understandable that different authors have used different evaluation metric for their specific studies. Pease see the following literature for further discussions on choice of evaluation metrics: Fielding and Bell [23], Guisan and Zimmermann [29], Pearce and Ferrier [60], Manel et al. [44], Fielding [24], Liu et al. [40], Vaughan and Ormerod [88], Allouche et al. [1].

Table 2 summarises the factors influencing application of ML techniques to ecological modelling and Table 3 presents the comparative performances of some of the selected studies found in the literature [36].

As can be seen, none of the modeling techniques is universally superior compared to other techniques across all applications. Comparative performances of the three traditional methods, namely, GLM, GAM and climate envelope model, shows GAM and GLM have comparable performances. Among the Machine Learning methods, the popular GARP technique produces moderate performance, while CART and ANN have shown mixed results. It may be noted that these examples did not include adequate number of applications of ANN. Jeschke and Strayer [36] have reported, overall, ANN performs better among the ML techniques applied to this problem domain. Robustness is a characteristic often attributed to ANN. The findings by Jeschke and Strayer [36] also validate this claim. The specialized climate envelope techniques such as BIOCLIM, FEM and DOMAIN show only moderate performance in general and often perform worse than the Machine Learning techniques. However, some of the relatively recent comparisons have claimed that newer techniques are likely to outperform more established techniques (e.g. the model-averaging random forests by Lawler et al. [39] and Broennimann et al. [9]; the Bayesian weights-of-evidence model by Zeman and Lynen [91]). However, as these methods have been used only in a handful of studies, claims about their predictive power is premature [36]. Finally, this comparative study reiterates the fact that success and failure of the modelling techniques is primarily dependent on the application including the data set and the goal of study.

Table 2 Factors influencing application of ml techniques to ecological modelling

Factor	Impact on ML technique	Possible solution
Very large data sets	EC, ANN and DT all are adversely effected	Enhanced algorithms, effective sampling, approximation; massively parallel processing
High dimensionality	EC, ANN and DT all are adversely effected	Reducing dimensionality; using prior knowledge to identify irrelevant attributes
Over-fitting	DT and some of the ANNs are adversely effected	Cross-validation; regularization
Dynamic environment	EC, ANN and DT all are adversely effected	Incremental methods capable of updating the patterns and identifying the patterns of changes
Noisy and missing data	DT is better equipped to handle this problem compared to others	Data smoothing; Statistical strategies to identify hidden variables and dependencies
Complex dependencies among attributes	EC, ANN and DT all are effected; however, handles better than traditional techniques such as GLM	
Interpretability of the generated patterns	EC = poor interpretability; DT and ANN = moderate to high interpretability	
Choice of test and training data	Effects EC, ANN and DT	Depends on goal of the study; however, generally independent validation is better than others
Model evaluation metrics	Effects EC, ANN and DT	Depends on goal of the study

Table 3 Comparative performances of ecological modelling techniques[a]

Study	Species	No of unique members of species	Performance evaluation metric	Comparative performance
Manel et al. [43]	Birds	6	Proportion of correct predictions, sensitivity, specificity, kappa and so on	ANN > GLM
Termansen et al. [82]	Plants	100	AUC[b] score, sensitivity	GLM > GAM > CART
Vayssieres et al. [89]	Oaks	3	Sensitivity, specificity, differential positive rate	CART > GLM
Lorena et al. [42]	Plants	35	AUC score	SVM[c]>ANN>DT>GARP
Robertson et al. [72]	Plants	3	Kappa	FEM>BIOCLIM
Johnson and Gillingham [37]	*Rangifer tarandus caribou*	NA	r, r_s	GLM>GARP
Elith et al. [20]	Animals, plants	226	AUC score, correlation, kappa	GAM>GLM≈BIOCLIM
Hernandez et al. [31]	Animal	18	AUC, sensitivity, kappa	GARP>BIOCLIM
Lawler et al. [39]	Mammal	100	AUC, sensitivity, kappa	Random forest>GLM>GAM≈ANN >CART≈GARP
Pearson et al. [62]	Proteaceae	4	AUC, kappa	GAM≈ANN>GLM>CART>GA >GARP>BIOCLIM
Schussman et al. [77]	*Eragrostis lehmanniana*	NA	Sensitivity, specificity, kappa	GLM>GARP
Randin et al. [70]	Plants	54	AUC score, kappa	GAM≈GLM
Zeman and Lynen [91]	Rhipicephalus appendiculatus	NA	Mean squared difference	Weights of evidence (Bayesian)> GAM
Meyard and Quinn [50]	Artificial species	18	AUC score, sensitivity, specificity, kappa	GAM>GLM>CART>GARP
Tsoar et al. [85]	Animals	42	Kappa	GARP>HABITAT>BIOCLIM

[a]All experiments used data splitting as the means to select training and test sets
[b]Area under curve
[c]Support vector machine

Conclusion

This paper presented a comprehensive review of applications of various Machine Learning techniques to bioclimatic modelling and broadly to ecological modelling. Some of the statistical techniques popular in this application domain have also been discussed. Factors influencing the performance of such techniques have been identified. Performances of these techniques when applied to ecological modeling have been compared based on studies reported in existing literature. It has been concluded that success or failure of application of the Machine Learning techniques to ecological modeling is primarily application dependent and none of techniques can claim superior performance as against other techniques universally. However, the identified factors or characteristics can be used as a guideline to select the ML techniques for such modeling exercises.

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nFTP: An Approach to Improve Performance of FTP Protocol on the Virtual Network Environment in the Same Physical Host

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Abstract

The future of the Internet is applications and services based on virtualization environment. The strong points of virtualization technology are high availability, high flexibility and the effective cost of application management. Currently, network applications are always running on some physical network. Based on virtualization technology there are two main approaches for network virtualization. First one is based on network device virtualization, the second one is based on network virtualization where connected network devices and servers are virtual machines. In the second approach, transmitting information between virtual servers is performed primarily based on the traditional network protocols. However, when the virtual machines of a virtual network are located in a same physical host, the traditional network protocols don't take full advantage of virtualization technology. The time for packets routing through the network devices (virtual machines) on the routing path is not reduced even though all virtual network devices are on the same physical host. In this paper, the authors offer a new approach to improve speed/performance of the network protocols on the virtual environment by directly copying data from one virtual machine to the other. Within the scope of this paper, to illustrate this idea, the authors focus on improving the performance of the traditional FTP protocol. The results of our experiments show that the performance of improved FTP protocol (nFTP) has increased significantly in the virtual network environment. This approach opens a wide range of research topics to improve performance of network protocols on virtual networks.

Keywords

Cloud computing • Virtualization • FTP performance improvement • FTP protocol for virtual network environment

Introduction

Virtualization technology is growing strongly in the recent years. There are many products that use virtualization technology to manage and allocate resources and services such as: VMware, KVM, XEN,... [1, 2]. When virtualization technology developed and widespread used, some new transmitting environments appear such as communication between the physical computer and the virtual machine (VM), or between the VM and the VM. Transmitting environments can be established on the same physical system or on different physical systems.

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_57,

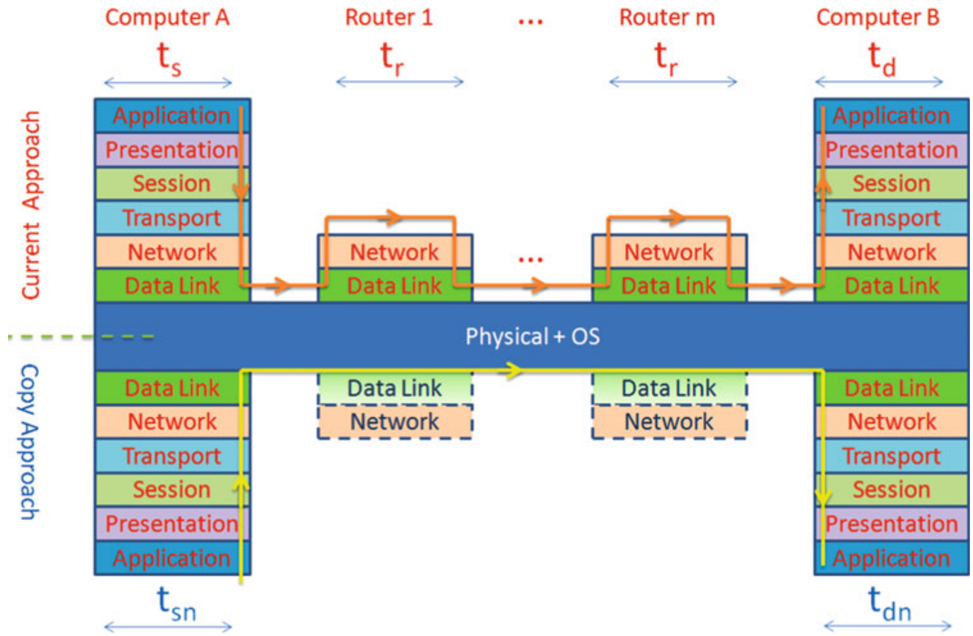

Fig. 1 Network traffic flow comparison between current approach [4, 11] and nFTP approach

Today, more enterprises tend to build their private cloud [3] in order to provide resources, services and network applications to meet their business requirements. In this case, Private Cloud Systems typically contain multiple VMs on the same physical system. Currently, communication between VMs uses the same protocols as between physical machines. Therefore, when packets are transferred between the VMs together, even on the same physical host, they are also inserted and removed the header when passing through each layer in the TCP/IP protocol stack [4]. This did not take the advantage of the reality that the source and the destination are VMs on the same physical host.

As some related works, some researches tried to improve the performance of network protocols on a virtual environment by removing the one or two last bottom layers of OSI reference model, but it still within the traditional framework of the TCP/IP protocol stack. vFlood [5], XenSocket [6], XenLoop [7], Fido [8], Xway [9] offer some approach to improve performance of inter-VM communication when the VMs are all on the same physical host. Some other researches based on bypass the processing of QEMU [10].

In this paper, the authors offer an approach to increase the performance of communication on the virtual network environment when VMs are in the same physical host. To illustrate this approach, the authors focus on improving performance of the typical network protocol, FTP protocol. The purpose of this approach is to choose a reasonable communication type in a virtual network environment. The solution creates an agent that running on each virtual machine and a service that running on the physical host. The agent determines the physical addresses (MAC addresses) of the source virtual machine and the destination virtual machine in the transmitted request. If two VMs are located in the same physical host, the service on the physical host will copy data from the virtual hard disk of the source VM to the virtual hard disk of the destination VM. In other case, the traditional FTP protocol is used.

Traditional Protocol

Data Transmission on the Traditional Network Environment

Speed of data transmission is affected by following main factors (Fig. 1):

- Collision checking on medium: Nodes on the network attempt to avoid collisions by transmitting only when the channel is sensed to be “idle” [11].
- Performance of router: Speed of switching and routing of router based on its power, the number of simultaneous arrived packet.
- TCP/IP Header Checking: Encapsulation and Decapsulation over each TCP/IP layers.

Thus, speed of transmission is depended on media, numbers of routers on the routing path when we use traditional network protocol.

To simplify the data transfer time calculation formula, the authors omitted some detail cost related to some TCP/IP layers. All costs are grouped into the following main cost categories:

Call t_s is the time to read/write data on hard disk of the source node.

Call t_r is the time to process packets on each router.

Call m is the number of routers. Call t_d is the time to write/read data on hard disk of the destination node.

Call T_1 is the time to transmit data based on traditional network protocol.

The following equal is valid:

$$T_1 = t_s + m.t_r + t_d. \quad (1)$$

Data Transmission on the Virtual Network Environment

To create compatibility for the operating system running on ×86 CPU architecture, KVM hypervisor [4] emulated standard network interface card (NICs). This emulation tasks are undertaken by QEMU, using dynamic translation mechanism. For each VM, KVM will allocate a QEMU process corresponding to the VM. TAP and bridge are virtual network devices that work at the data link layer. When a VM is created, KVM will define a corresponding TAP device. QEMU process of the VM will allocate memory for the TAP device. Each TAP device is a NIC of a corresponding virtual machine. When host kernel receives packets from the TAP device, it must determine destination of this packets, to other virtual machine or to other physical host. TAP only sends and receives data from user-space process and it doesn't need to connect to physical devices. Thus, TAP must use a bridge if we want to transfer data between physical NIC devices. All TAP of VM and physical NICs are connected to a bridge. Bridge works as a data transmission channel between TAPs and physical NICs (Fig. 2).

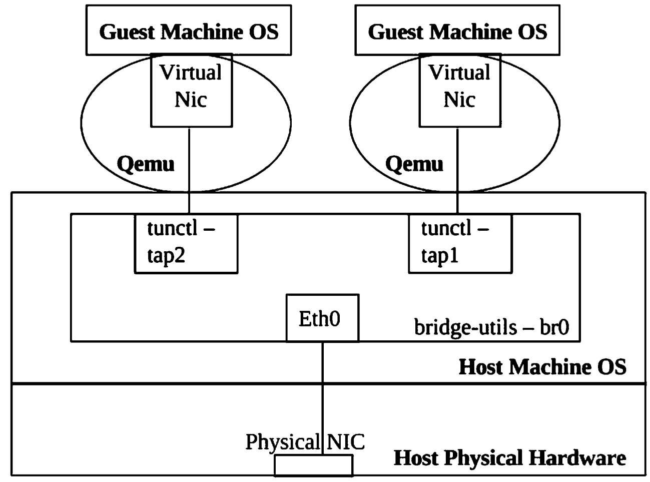

Fig. 2 Virtual network structure [12]

Table 1 Delay of sending time in detail of emulation network driver model [10]

Time (microseconds)	Step name
0.58	VM exit
0.30	KVM interrupt handling
3.02	QEMU emulation
3.47	TAP transaction
1.72	Bridge transaction
0.21	VCPU load
9.30	Total

Para-Virtualized Network Driver [10]

In the full virtualization, the hypervisor must emulate hardware devices. Because this emulation reduces the performance of the VM, para-virtualization was build. Para-virtualization is a technique used to increase performance and simplify operations of hypervisors and VMs. This technique requires VMs to install the drivers provided by the hypervisor (known as the front-end driver) for interacting with back-end drivers of hypervisor. Front-end and back-end driver are referred to as para-virtualized drivers. The communications between VMs or between a VM and physical host via para-virtualized drivers would be much easier and it reduces context switching of CPU (switch between root and non-root modes). The two main limitations of para-virtualization:

- Guest Operating System must install front-end drivers to use this technique.
- Because para-virtualized drivers are developed for each hypervisor (Xen, VMWare,. . .), when a VM is moved from one hypervisor to another hypervisor must to reinstall new front-end drivers.

Virtio Driver [10]

Virtio was created to solve the second limitation of para-virtualization. Virtio is integrated into Linux kernel since version 2.6.25 onwards. The virtio driver like generic drivers for various hypervisors, it improves compatibility between hypervisors when we use para-virtualization technique. When a VM is installed virtio drivers, it can interact with any hypervisor, if the hypervisor is installed virtio back-end drivers. There are five main virtio driver types: Virtio-net, Virtio-blk, Virtio-ballon, Virtio-pci, Virtio-console. In this paper, the authors focus on Virtio-net (for networking).

According to Gal Motika et al. [12], comparison of delay time between emulation network model and Virtio Para-Virtualized driver model are shown in Tables 1, 2, 3 and 4.

Table 2 Delay of receiving time in detail of emulation network driver model [10]

Time (microseconds)	Step name
1.72	Bridge transaction
2.70	TAP transaction
2.57	QEMU emulation
0.30	KVM interrupt handling
0.21	VCPU load
7.50	Total

Table 3 Delay of receiving time in detail of Virtio para-virtualized driver model [10]

Time (microseconds)	Step name
1.72	Bridge transaction
2.56	TAP transaction
0.78	Virtio back end
0.35	Virtio front end
5.41	Total

Table 4 Network bandwidth comparison between emulated driver model and Paravirtualized Virtio driver model

	Emulated driver (Mb/s)	Paravirtualized Virtio driver (Mb/s)
Transmit bandwidth	181	286
Receive bandwidth	371	570

The paravirtualized virtio driver model is faster than emulated driver model. However, paravirtualized Virtio driver model was still according the rules of the OSI reference model. In this paper, the approach of the authors improve the speed of the virtual network environment by using Virtio technique and directly copying data from source virtual hard disk (source VM) to destination virtual hard disk (destination VM) without intermediate router's processing (Table 5).

Our Approach: nFTP

Advantages of our Approach

Speed of data copying depends mainly on the disk header and rotation speed of hard disk [13]. It is faster than speed of transmission media. Thus, in a virtual network environment, when a virtual network is located on the same physical host, this copying can have higher efficiency than the traditional network protocol. Our solution is shown in Fig. 3.

Call t_{sn} is the time to read/write data on hard disk of the source node.

Table 5 Delay of sending time in detail of Virtio para-virtualized driver model [10]

Time (microseconds)	Step name
0.26	Virtio_add_buff
1.71	Virtio-net: hande_tx
3.32	TAP transaction
1.72	Bridge transaction
7.01	Total

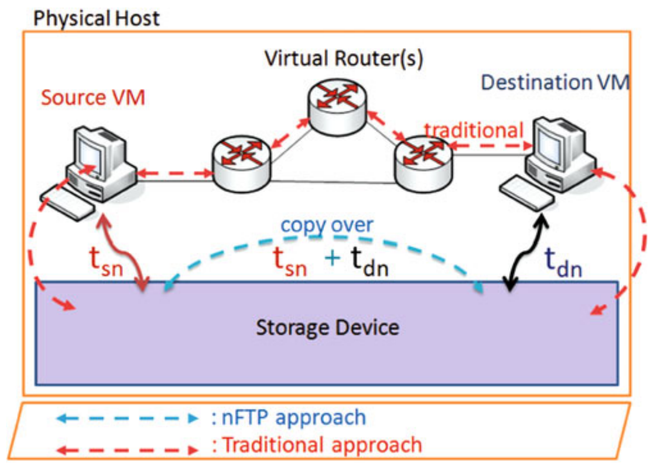

Fig. 3 Traditional approach [4] and nFTP approach

Call t_{dn} is the time to write/read data on hard disk of the destination node.

Call T_2 is the time to transmit data based on nFTP approach.

The following equal is valid:

$$T_2 = t_{sn} + t_{dn}. \tag{2}$$

If we assume that the hardware configuration is the same, reading and writing speed of hard disks is the same, the transmission times are the same. That mean: $t_s = t_{sn}$, $t_d = t_{dn}$, and t_r is the same with any router.

Because of n, m, and $t_r \geq 0$,

$$T_1 - T_2 = m.t_r \geq 0 \tag{3}$$

So,

$$T_1 \geq T_2 \tag{4}$$

The formula (3) show that, the more, number of packets and number of routers are large (data size is big), the more, T_1 greater than T_2.

From the arguments above, and because the FTP protocol is widely used and often transmit a large data, then the FTP protocol is chosen to implement a testing for this approach.

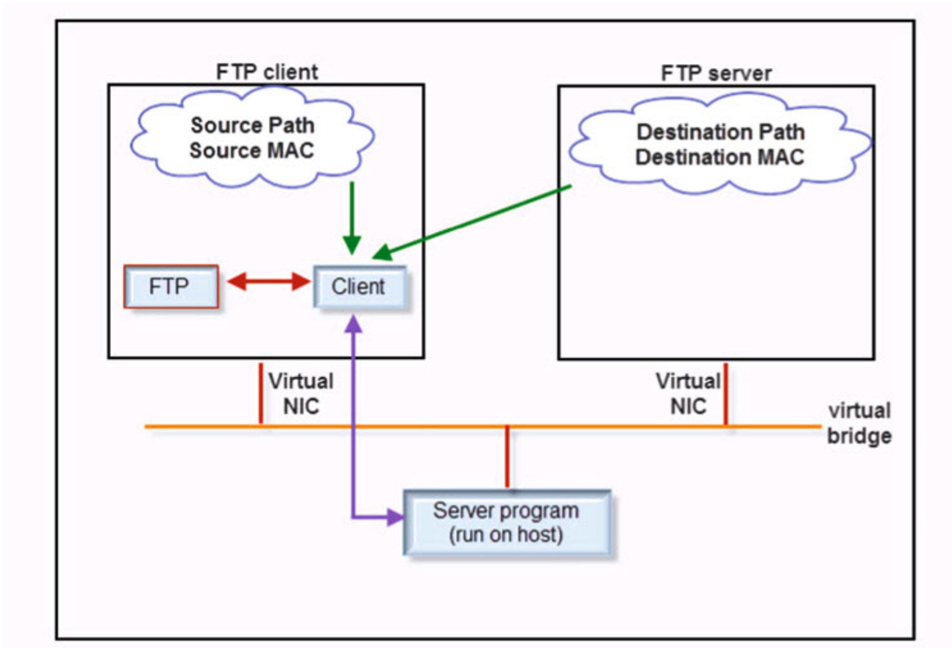

Fig. 4 Architecture of nFTP

nFTP System Model

The system has two main components: Client Program: Agents run on guest VMs; and Server Program: Management System run on the physical host (Fig. 4).

Client Program is responsible for receiving file transferring requests of virtual machines. It analyzes requirements, identifies source path, source MAC, destination IP and destination path. Then it sends these parameters to Server program. Figures 5 and 6 show all detail functions of Client Program.

Server Program will determine destination MAC address of Server Program will determine destination MAC address of the corresponding Destination IP, check the "Source MAC" and "Destination MAC" that located on the same physical host. Then it identifies "Source DomName" and "Destination DomName", creates mount points and copies data from source virtual hard disk (source VM) to destination virtual hard disk (destination VM). Figure 7 show all detail functions of the Server Program.

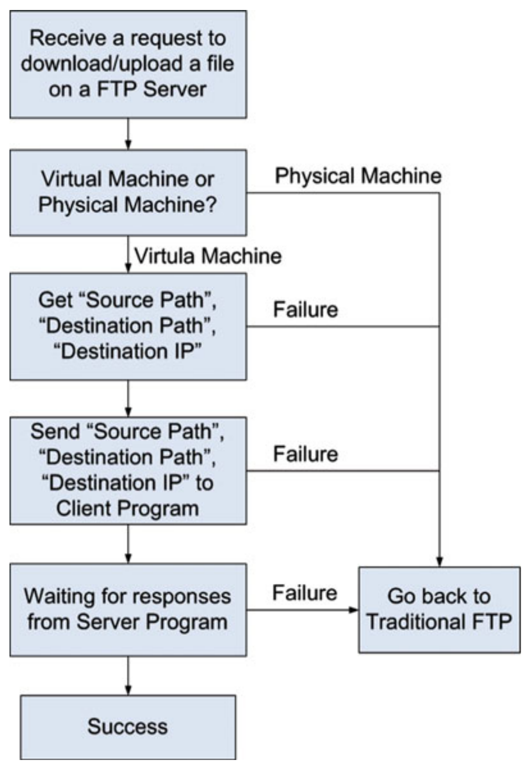

Fig. 5 The process diagram of new FTP Client

Experimental Results

Test Model

To test the effectiveness of this approach, the authors build the test model as follows:

- Hardware configuration of the physical host: CPU: Intel® Core™2 Duo—E7500—2.93 GHz, HDD 320 GB–5,400 rpm, Memory 4 G.
- Operating of physical host and virtual machines are Fedora 16 [14]. Hypervisor is KVM [1]. Emulated network device tool is QEMU [15].
- CPU load generator is LookBusy [16].

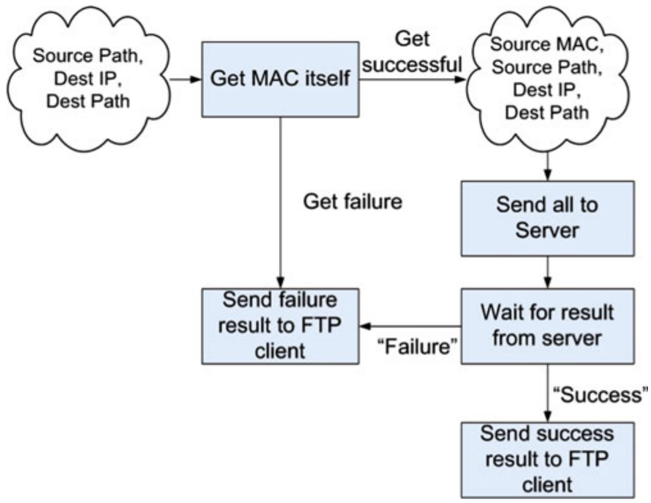

Fig. 6 The process diagram of client program

Fig. 7 The process diagram of server program

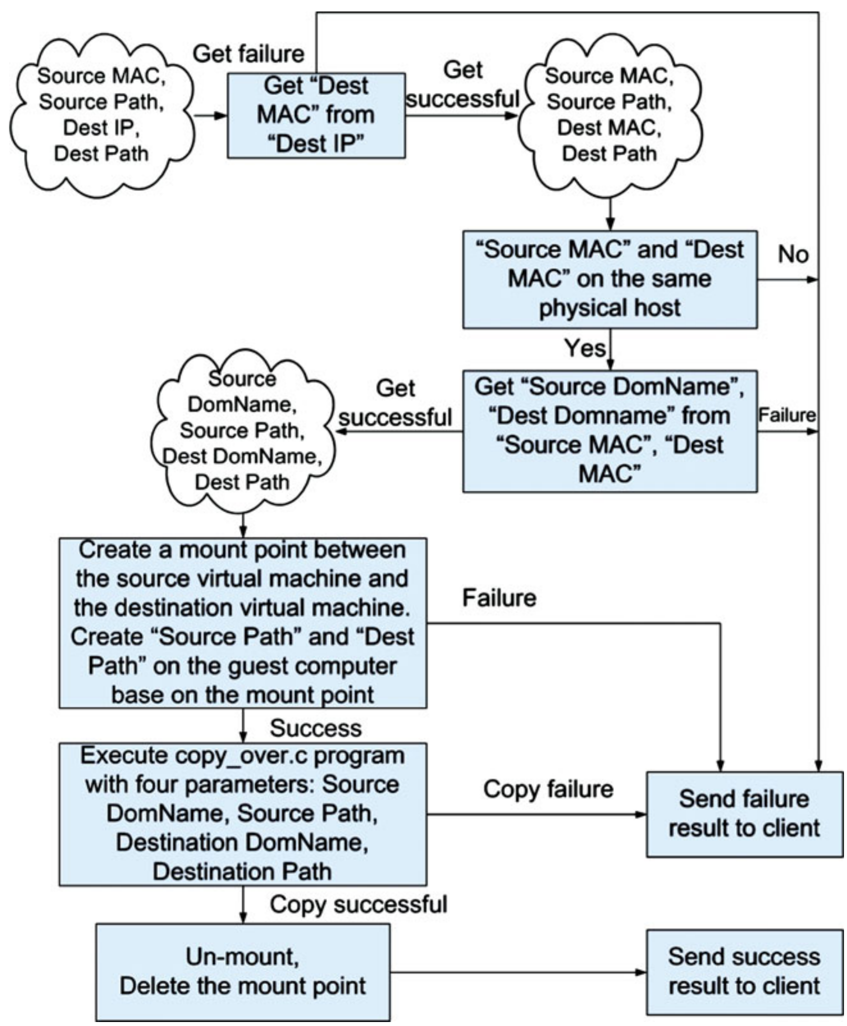

Table 6 Time of data transmission of nFTP approach with various numbers of routers and various CPU loads

CPU load	0 %				25 %				50 %				75 %			
Router size	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
4 GB	180.0	182.0	189.0	199.6	200.0	205.1	207.0	209.3	202.0	205.0	207.0	210.4	210.0	212.5	216.7	218.6
3 GB	118.8	122.0	124.6	125.9	128.0	132.6	135.0	137.0	136.9	137.0	138.7	140.0	142.9	147.5	149.0	157.0
2 GB	79.0	80.5	82.0	85.8	79.5	82.2	83.8	88.2	88.6	89.0	91.0	92.5	94.0	96.0	98.3	99.5
1 GB	31.0	32.0	32.5	35.0	31.0	33.6	36.7	39.1	40.0	40.8	41.0	42.0	47.2	48.0	49.4	50.0
500 MB	15.0	15.5	16.0	17.0	15.7	16.0	16.8	17.2	18.0	19.3	19.8	20.7	23.9	24.2	25.6	25.9

Table 7 Time of data transmission of Virtio approach with various numbers of routers and various CPU loads

CPU load	0 %				25 %				50 %				75 %			
Router size	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
4 GB	190.0	197.0	109.0	219.7	191.0	198.0	196.5	216.0	210.0	214.0	221.0	236.0	230.0	247.0	272.0	297.4
3 GB	135.0	139.8	143.0	154.7	136.5	138.0	146.5	159.0	147.0	153.5	165.0	177.0	170.8	183.5	200.0	217.9
2 GB	88.0	90.5	96.5	103.0	89.8	91.8	98.1	105.0	98.0	103.0	106.5	112.0	112.3	123.0	132.0	140.0
1 GB	41.3	47.4	50.0	53.0	41.7	48.1	51.5	53.9	48.0	51.7	54.0	55.2	58.4	60.1	62.0	63.0
500 MB	20.0	23.7	25.0	27.0	20.5	22.6	25.0	27.8	22.5	24.6	26.0	28.7	28.0	29.8	30.8	32.8

Table 8 Time of data transmission of traditional approach with various numbers of routers and various CPU loads

CPU load	0 %				25 %				50 %				75 %			
Router size	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
4 GB	290.0	401.0	548.0	659.0	291.0	402.0	550.0	667.0	292.0	410.0	553.0	698.0	295.0	448.0	585.0	729.0
3 GB	210.5	296.0	410.0	530.0	212.0	297.0	411.0	532.0	213.0	307.0	409.0	534.0	216.0	335.0	438.0	540.0
2 GB	140.0	201.0	264.5	332.0	141.0	202.0	265.5	335.5	142.5	207.0	270.0	345.6	144.0	223.0	294.5	364.0
1 GB	72.5	101.0	133.5	170.0	73.0	102.0	134.5	171.0	76.0	105.0	139.5	178.0	79.0	112.0	148.0	181.0
500 MB	36.5	49.1	64.5	83.2	37.0	49.4	66.0	84.0	38.0	49.8	67.5	85.0	39.5	52.7	74.5	88.3

- Tested objects: data transmitting speed of traditional FTP method (non-virtio FTP), the virtio FTP method [10], and the method proposed by the authors (nFTP).

The approach of the authors bypasses encapsulation and decapsulation process on intermediate routers. Therefore, the authors build the test model with different number of routers. In order to clearly see the difference of transmitted data time between the approaches, the authors use test files with different of size in each test case. As guessed, the speed of data copying is affected by speed of storage devices, because the approach of the authors (nFTP) based on directly data copying. When CPU load increases, the nFTP is faster than other two approaches. Therefore, the authors tested on various case studies based on various CPU loads of the physical host to examine the advantages of this approach compared with other approaches. In test cases, the number of routers is: 0 (directly connection), 1 router, 2 routers and 3 routers. Size of tested file is: 4 GB, 3 GB, 2 GB, 1 GB, and 500 MB. CPU load of physical host are: 0 % (Don't run other applications), 25, 50 and 75 %.

The test results are shown in Tables 6, 7 and 8.

According to the test results, in Table 6, we can see the data transmission time of nFTP approach don't increase much when the number of router increases, while the Virtio approach (Table 7) increases and the most increased is the traditional approach (Table 8). The results in Tables 6, 7 and 8 show data transfer time of all three approaches increases proportional to the size of test file. Thus, to compare the performance of the approaches, the authors only focus on the test results in the case of three routers and 4 GB of tested file size, but still no loss of generality.

In Fig. 8 shows data transfer rate of nFTP approach and Virtio approach are faster than traditional approach.

In Fig. 9 shows nFTP approach is faster than Virtio approach. Moreover, in case of high CPU load, nFTP approach is very effective when it is compared with virtio approach (the right edge of yellow area is longer the left edge). Thus, through the experimental, nFTP is faster than other two approaches. The data transmission of nFTP does not increase rapidly when number of router increases (Table 6). Thus, nFTP is an approach of great significance in the case of VMs on the same physical host or the same

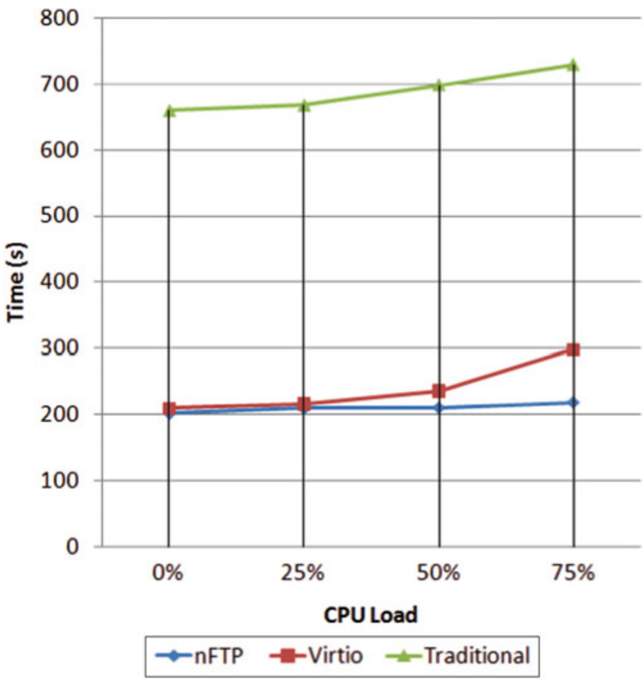

Fig. 8 Performance comparison between traditional, nFTP and virtio approach in the case study: three routers and test file size is 4 G

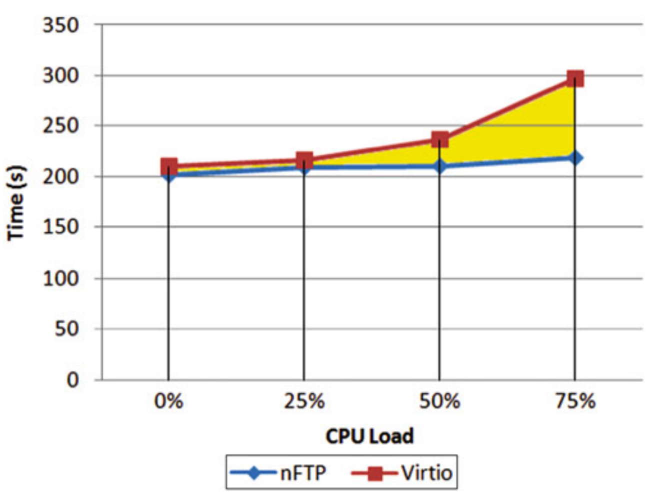

Fig. 9 Performance comparison between nFTP and Virtio approach in the case study: three routers and test file size is 4 GB

storage system and the large number of routers. When nFTP is compared with Virtio approach, data transmission time of nFTP doesn't increase significantly in case of increasing CPU load. That mean, nFTP is the best solution if the physical host has high CPU load (Fig. 8).

Conclusion and Future Works

This approach of the authors is generally faster than other traditional FTP protocols when the VMs are located on the same physical host, and many routers and high CPU load. In this paper, speed of FTP protocol in a virtual network environment is improved with remarkable speed. It opens up several area researches, such as improve the speed of the DNS protocol, HTTP,... in a virtual network environment. A basic approach is focused to develop a mechanism that allow you identify communications between VMs on the same physical host and automatically switch to the improved network protocol instead of editing each protocol at application layer. In this paper, the authors haven't focused to the aspects of security, privacy, authorization,... of the nFTP service yet. The next research topics will resolve the aspects. Other next research topic try to improve performance of protocols at transport layer (TCP/UDP) based on nFTP approach.

Acknowledgment We would like to thank Dr. Richard WM Jones (Emerging Technologies, Red Hat), Dr. Kaskenpalo Petteri (Faculty of AUT) who provided some useful material. We thank Cloud Research Team of University of Science at Ho Chi Minh City who helped the authors to finish this paper.

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Hardware Architecture Review of Swarm Robotics System: Self Reconfigurability, Self Reassembly and Self Replication

Madhav Patil, Tamer Abukhalil, Sarosh Patel, and Tarek Sobh

Abstract

Swarm robotics is one the most fascinating and new research areas of recent decades, and one of the grand challenges of robotics is the design of swarm robots that are self-sufficient. This can be crucial for robots exposed to environments that are unstructured or not easily accessible for a human operator, such as the inside of a blood vessel, a collapsed building, the deep sea, or the surface of another planet. In this paper, we present a comprehensive study on hardware architecture and several other important aspects of modular swarm robots, such as: self-reconfigurability, self-replication, and self-assembly. The key factors in designing and building a group of swarm robots are cost and miniaturization with robustness, flexibility and scalability. In robotics intelligence, self-assembly and self reconfigurability are among the most important characteristics as they can add additional capabilities and functionality to swarm robots. Simulation and model design for swarm robotics is highly complex and expensive, especially when attempting to model the behavior of large swarm robot groups.

Keywords

Hardware implementation • Self-Assembly • Self-Reconfiguration • Self-Replication • Swarm Robots

Introduction

Over the past decade, an increasing number of research and development activities related to modular swarm robotics is attracting considerable attention and interest in industry and academia. This interest inspired by, among other things, the emergent behavior observed in social insects such as ants, bees, wasps, termites, etc. [1]. Self-reconfiguration, self-assembly and self-replication are the main distinguishing characteristics of swarm robots, and a dream long held by many researchers in the field of robotics is to develop fully autonomous robotic systems with these characteristics [2]. As with many new technologies, this field is growing rapidly and becoming more complex, but there remains much to accomplish in the development of swarm robotics intelligence and swarm robotics hardware as the performance of a swarm robotics system depends greatly on its mechanical and electronic control design [3]. As a swarm multi-robot system becomes more complex, each robot must still follow simple rules to perform a task or any application.

Swarm robot groups are usually homogeneous and controlled by a centralized or hierarchical system, depending on the application. Most of the robot platforms used in such swarm groups have the capability to assemble themselves according to the requirements of the task. Self-assembly is a process in which a group of swarm robots comes together to form a temporary large body structure capable of performing a job that is beyond the capability of single swarm robot [4]. Christensen, O'Grady, and Dorigo describe a robotic system

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_58,

that exhibits this kind of self-assembly. In this system, the basic units are themselves robots that can function either independently when disconnected from one another, or they can function collectively when connected together to form a metastructure. The Christensen/O'Grady/Dorigo system demonstrates this kind of transformation of a collection of independent robots through a variety of different metastructure morphologies in physical hardware. Given enough units, if any individual unit in such a metastructure fails, the system would self-repair by replacing nonfunctional units with functional ones.

Self-reconfiguration is a process by which a robot metastructure constructed from physical structures or subsystems of [5] modular robots autonomously self-organizes and changes shape in order to adapt to different tasks or classes of terrain. For instance, some modular robots may transform into snakes in order to follow a tunnel and then may transform into quadrupeds to go up stairs. In self reconfiguring, swarm modules are able to connect and disconnect without any human interaction as they offers such advantages as versatility, adaptability, robustness and cheap production over traditional robots [6, 7]. Due to these advantages, swarm robots exhibiting self-reconfigurability and self-assembly can be used to handle a wide range of tasks in an unknown or dynamic environment such as search and rescue operations after a fire or earthquake, undersea mining, planetary exploration, battlefield reconnaissance, and other application like service robotics and entertainment.

Fifty years ago, in 1947, Von Neumann proposed an automoton model sufficiently complex to reproduce itself [8–10]. Self-replication is another one of the characteristics of a modern swarm robot, in which several robot modules connect with each other to form an exact copy of the original robot [4]. The concept of kinematic self-reproduction has been applied in many research areas such as cellular automata, nanotechnology, macromolecular chemistry, and computer simulations. In the 1950s and 1960s, Penrose presented the first implementation of a passive self-replicating machine. He showed that simple units or "bricks" having certain properties could be employed to build a self-reproducing machine under external agitation. The replicated robot function is the same as the original robot so that it can perform the same task. Only a few, high-level modules have successfully demonstrated the ability to self-replicate, primarily due to the great complexity of the process. Such a process is extremely challenging for low level modular robots.

This paper is organized as follows. First, we introduce the reader to background material and provide an overview of related work on swarm robotics hardware architecture. Next, we provide more detail on sensors, actuation and manipulation, controllers and communication, and power options. Finally we offer conclusions on our survey results.

Swarm Robot: Self-Reconfigurability, Self-Replication

In this section, we provide a brief survey of related work on swarm robot self-reconfigurability, self replication and self reassembly. Modular robots are still in the process of becoming more flexible, autonomous, and more robust [11, 12]. Like any other robot, a swarm robot has two main organs; hardware and software. Software is the brain of the system, which gives a simulation environment to the functioning of the robot. The hardware brings directions stimulated by the software into action. When many such inter-communicating robots are deployed to work together, swarming action comes into play. However, only limited hardware platforms have been developed and used so far.

According to [12], self-reconfigurable robots are classified into three main types: chain, lattice and mobile reconfiguration systems. In the chain and lattice types, each module typically remains connected to the (larger) modular robot at one or more points, while in mobile modular systems, the system self-reconfigures by having modules detach themselves from the modular robot and move independently to another location to reconnect. Self-reconfigurable robots have proven to be capable of self-repair [13, 14], self-assembly, and locomotion over a either a plane surface or over widely varied terrain [15].

Self-reconfiguration in a homogeneous system is simpler than in a heterogeneous system, but a heterogeneous swarm robot system might be more time-efficient at accomplishing certain tasks. Because the modular robot metastructure created by such a swarm system will be more compact due to the specialized capabilities of the modules [16].

Many sophisticated swarm intelligence robot platforms have been built to date by considering cost and functionality along with a flexible distributed intelligence structure. Some examples are given below.

Lattice-Based Robot Architecture

In lattice architectures, the mobile robot units are connected and arranged in regular three dimensional cubic or hexagonal grid patterns. The lattice architecture offers relatively simpler reconfiguration and control, since motion is accomplished in parallel within an open loop framework. Homogeneous "molecubes" based on a lattice self-reconfigurable robot are demonstrated in [17]. Each "molecube" module is a 10-cm cube, and one half of it can swivel relative to the other half. Each half can bind with one additional module by using electromagnets. Lattice-based self-reconfigurability and self-replication of a four-module entity is also demonstrated in [18] when the system is provided an ordered supply of additional units. The system executed a

Fig. 1 Lattice type architecture [20] (copyright @ 2007 Brandt et al.)

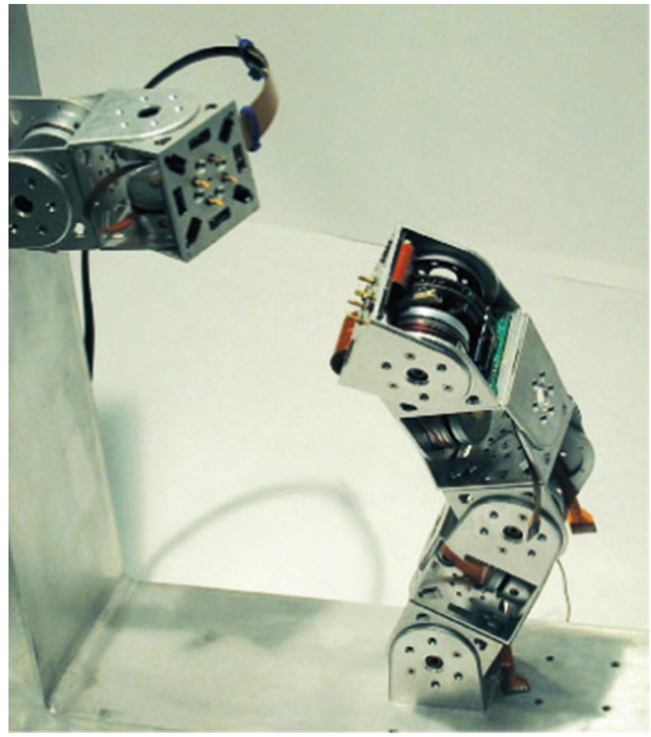

Fig. 2 Chain type architecture [3] (copyright @ 2007 Yim et al.)

predetermined sequence of actions. ATRON is yet another lattice-based system, in which modules are arranged in a subset of a surface centered cubic lattice [19]. ATRON modules composed of two hemispheres joined by a single revolute joint, as shown in Fig. 1 [20]. In [20], Brandt, Christensen and Lund discuss the mechanical design of ATRON and its resultant system properties, based on FEM analyses and real-world experiments. Fracta [21] and Metamorphic are also homogeneous 2-D lattice-based mechanical hardware characterized by hexagonally shaped robot modules. Other lattice-based robots like 3-D SRS, I-Cube [22], and Proteo [23] are also homogeneous in nature, which provides for easy self-reconfiguration of these modules, but the hardware implementation is very complicated due to the geometric symmetry required for actuation and connection with other modules to provide more DOF's (Degrees Of Freedom).

Chain-Based Robot Architecture

Chain-based architectures have units that are connected together in a string or tree topology. The chain or tree can fold up physically to fill arbitrarily shaped spaces, but the underlying architecture is still serial. Through articulation, chain architectures can potentially reach any point or orientation in space and are therefore more versatile than some other architectures, but computationally they are more difficult to represent and analyze, and hence are more difficult to control [24]. PolyBot [13, 25] is modular chain robot that can configure its shape without human assistance. Yim et al. [3] have demonstrated the ability of PolyBots to self-reconfigure and self-reassemble with other PolyBots despite the limitation of each PolyBot to a single DOF, as shown in Fig. 2. CONRO [26–28] is a homogeneous modular chain robot with a processor, power supply, sensors, and actuators on each module. The CONRO robot has demonstrated the capability of self-assembly. M-TRAIN [29] is another modular, distributed, self-reconfigurable homogeneous robot module which can change configuration by changing positions and connections with other M-TRAIN modules.

Mobile-Based Architecture

Mobile architectures have units that use the environment to maneuver around and can either hook up to form complex chains or lattices, or form a number of smaller robots that execute coordinated movements and together form a larger "virtual" network. CEBOT [30] was proposed by Fukuda et al. with dynamically reconfigurable robotic systems and has heterogeneous modules with various different functions. CEBOT has gone through considerable development, and the later versions are called CEBOT Mark 1, 2, 3, 4 [31]. CYBOT [32] is another type of a medium-powered mobile robot that is cheap enough to mass produce and hence

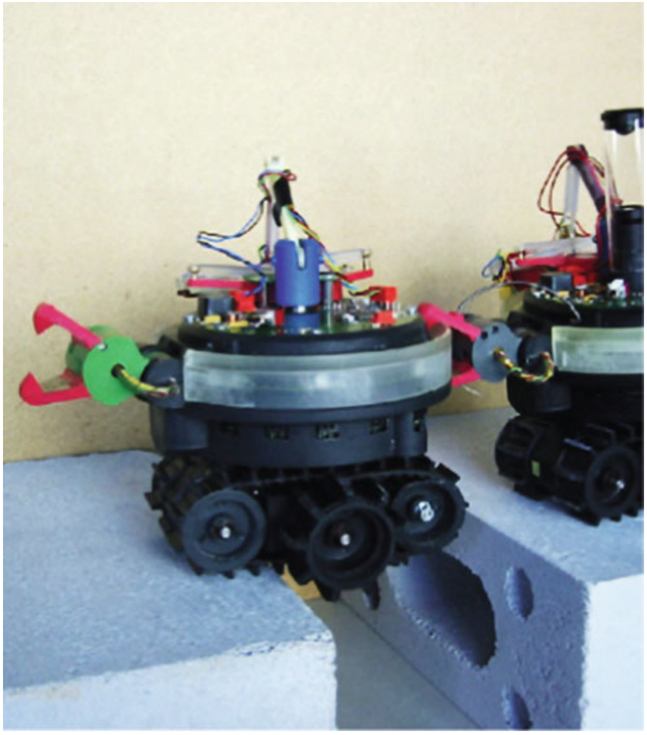

Fig. 3 Mobile type architecture [36] (copyright @ 2003 Mondada et al.)

Table 1 Classification of swarm robots

System	Class	DOF	Reference(s)
CEBOT	Mobile	Various	Fukuda et al. [31]
Polypod	Chain	2	Yim [68]
Molecule	Lattice	3	Chirikjian et al. [60]
CONRO	Lattice	4	Kotay and Rus [6]
Polybot	Chain	2	Castano et al. [61]
Metamorphic	Chain	1	Golovinsky et al. [62]
Telecube	Lattice	6	Suh et al. [63]
I-Cube	Lattice	3	Unsal and Khosla (2001)
Pneumatic	Lattice	2	Inou et al. [67]
Uni Rover	Mobile	2	Damoto et al. [64]
M-TRAN	Hybrid	2	Murata et al. [29]
Atron	Lattice	1	Brandt et al. [20]
Swarm-bot	Mobile	3	Groß et al. [65]
Superbot	Hybrid	3	Shen et al. (2006)
Molecube	Chain	1	Studer and Lipson (2006)
Miche	Lattice	0	Gilpin et al. [66]
ACM	Chain	Various	Hirose and Mori (2004)
Miniturized	Hybrid	0	Tomita et al. [14]
Fractum	Lattice	2	Yoshida et al. (1999)
M-TRAN II	Hybrid	2	Kurokawa et al. (2003)

assemble an interacting swarm. Gupta [33] proposed a low cost mobile module, the AUTOBOT robot, which can estimate the distance of obstacles and recognize multiple robots in an environment. The AUTOBOT module is capable of performing short-range communication using a 2.4 GHz radio module and has 2 h of battery backup power.

The S-BOT [34] is a fully autonomous small wheeled cylindrical robot, 12 cm in diameter, 19 cm high, weighing approximately 700 g, and is equipped with a variety of sensors. S-BOT's mobility is ensured by a differential drive system and mobile robot attachment architecture capable of clinging to other S-bots similar to itself by using a gripper. Dorigo [35] has run set of experiments in which 18 S-bots demonstrated coordinated motion on rough terrain, hole and obstacle avoidance, self-assembly, cooperative transport, environmental exploration, and path formation. Recently, Swarm Bots (S-Bots) [36] have become one of the most popular swarm robot platforms because of their extreme plasticity, high degree of physical adaptation, and minimal requirement for human interaction and monitoring (Fig. 3). IROBOT is another popular platform frequently used for swarm research. McLurkin and Yamins [37] describe work in which researchers implement an algorithm on a group of 25 IRobot SwarmBots and collect performance data. Each SwarmBot is mobile and has four IR transceivers at its corners, allowing communication with nearby robots and facilitating determination of the bearing, orientation, and ranges of its neighbors. A 32 bit micro processor is used as controller and all robots are homogeneous. Red, Blue, Green LEDs and a MIDI audio system are used to provide audible and visual indications for monitoring the internal state of the robots.

Alice [38, 39] is a small rectangular mobile robot with dimensions of 22 × 21 mm, driven by two high efficiency SWATCH motors for locomotion, controlled by a PIC16F877 microcontroller with 8 K word of Flash EPROM program memory. Alice has four IR proximity sensors for obstacle detection, a short-range robot-to-robot communication system, and an IR receiver for remote control. Also, there are a wide variety of auxiliary modules for extending its capabilities, such as a linear camera, RF, and gripper modules.

E-puck [40] is a circular robot with a diameter of 70 mm, driven by two stepper motors for locomotion, controlled by a dsPIC 30F6014A microcontroller with 144 KB of program memory and 8 KB of RAM. E-puck has eight IR sensors for measuring proximity to objects and for measuring ambient light. It has a speaker for audible feedback, three directional microphones that can be used for sound localization, and a 3-axis accelerometer. The robot has a color camera, a number of LEDs to signal/show its state, and Bluetooth for its main wireless communication channel. The robots can be programmed via the Bluetooth communication channel.

Table 1 below lists a number of self-reconfigurable robots, their classification and source of relevant reference information:

Hardware Architecture

The hardware of robot swarms consists of a broad range of components, including a wide variety of sensors, actuators, controllers, cameras etc. It is common practice to use hardware customized for specific applications, resulting in an increased degree of heterogeneity which in turn results in increased complexity for software developers. The nature of the tasks and the field of application influence the hardware architecture of a swarm robot, which must have the ability to navigate in dynamically changing environments without being third-party interaction, human or otherwise. The choices of appropriate sensors in robot swarms help the individual robots to perceive the various physical properties of their surroundings. Based on measured data, the swarm robots may conclude that one or more particular actions are necessary based on their current state. They will then activate and control actuator devices to interact with and influence their environment. In this section we review a variety of hardware architectures for swarm robots based sensory platform, actuation, locomotion, controller, and power supply.

Sensors Platform Review

Sensors are used to provide information about the surrounding environment to the controller—a process known as mapping. In swarm robotics, sensors are used to detect obstacles, to find targets, to find paths, and for communication. There are many different type of sensors used for swarm robots, but the IR Proximity Sensor [4, 7–13, 16, 17, 28, 35] is most commonly used, because it is a chip, small in size, easy to mount, and able to detect objects at a distance of 5–15 cm depending on the color of object. Such an IR sensor is shown in Fig. 4. An IR proximity sensor works by applying voltage to a pair of IR light emitting diodes, in response to which they emit infrared light which propagates through the air. Once the emitted light hits or is blocked by an object, it reflects back to the sensor. The closer the object, the stronger the intensity of reflected light will be. Geunho [41] addressed practical design and hardware implementation of DRIr (Dual Rotating Infrared Sensor) proximity sensors for mobile robot swarms. These sensors are characterized by low cost, high reliability, and easy integratability into commercial mobile robots. The DRIr also provides robots with full 360° azimuth scanning and controllable range-tracking capabilities and the operation functions controlling the observation motions were realized. Another type of sensor used in swarm robots is the Laser Range Finder (LRF) sensor, which has higher speed, accuracy, and resolution than LED-based IR sensors.

Fig. 4 IR proximity sensor module

LRF sensors have been used in various applications of mobile robots, but such applications are limited due to the high expense of LRF compared to other proximity sensing techniques [42]. Another type of proximity sensor is the Sonar or Ultrasonic sensor [43, 44], providing a mobile ultrasonic relative positioning system (URPS) that can be used by robots to detect the distances and angles of surrounding robots in relation to each other. Sonar time-of-flight distance sensor measurements work over a longer range than Infrared sensors, but can be easily affected by the hardness of objects, which can result in undesired measurement variation due to differences in how sonar waves are reflected and refracted by varying surface properties.

Some swarm robots use a vision system such as a camera to determine the position of other swarm robots as well for path finding and localization [34, 35]. The S-Bot (Swarm Bot) uses a VGA-resolution omni-directional camera for visual communication with other robot units and to determine the position of a target for long and short distance sensing. LEDs of different colors are used for visual signaling with other robots. In some of the swarm robot modules [45], omni-directional microphones, humidity sensors, temperature sensors, axis accelerometers, incremental encoders, and torque sensors are used. Sometimes odometry sensors are also used to aid in exploring all of the positions of swarm modules in a working environment.

Actuation and Locomotion Platform Review

The goal of a fully autonomous swarm robot team is to self-navigate, grasp objects, and physically interconnect with each other to accomplish self-reconfiguration, self-reassembly, and self-replication by means of a gripper or manipulator. Another goal is the transport of a heavy object from one location to another location in any type of terrain with the help of locomotion units such as wheels, tracks, treels (track/wheel combinations), or legs (quadrupedal, hexapedal etc.). Sensors and actuators must be selected and designed while considering constraints such as power consumption, voltage, driving signals (ideally pure digital), size and cost.

An artificial localization of swarm robots is mainly classified into two categories: absolute positioning and relative positioning [22]. In some swarm robots, a GPS system (Global Positioning System) is used to navigate in an unexplored environment. The GPS system consists of a number of satellites (originally 24, currently 32) in earth orbit, each transmitting time and position information that can be used by any receiver on or near the earth with an unobstructed view of at least four satellites to determine its position and altitude. The robot swarm can use the trilateration method to calculate absolute location to with a predetermined accuracy error. The accuracy error, the group deemed, isn't critically important since the robots can communicate with each other permitting them to determine relative location with respect to one other. When they localize with each other, the searching algorithm allows the robot to cover more area with much more efficiency. However, as a GPS system for determining absolute position is relatively expensive, another simple localization technique known as odometry is commonly used. This technique is accurate in the short-term and inexpensive. This technique uses wheel revolution data to determine linear displacement relative to the floor. The drawback to this technique is that, it is highly sensitive to error; that is, if there is a slight error in calculation, then the entire set of location calculations is skewed. The Servo motors are used for the locomotion in the swarm robots in addition with an incremental encoder or odometry unit. The actuation modules are of the following types.

Wheeled Swarm Robot

This swarm robot module might have two wheels for locomotion driven by servo motors. Most mobile robots only provide simple motion control by switching the DC servo motors on and off. E-puck [40], Alice [39], and Sumobot use a 2-wheel robot module, while SamBot [34] is maneuvers by means of a multi-crawler robot created by self-assembly. The three-wheel [32] and Boe bot platforms are also used in swarm robots, with gear assembly attached with a DC motor. The shape of the platform might be triangular or circular. Between 1995 and 1997, Takeshi Aoki, Yuki Murayama and Shigeo Hirose, [46] built an omni-directional three-wheel planetary exploration robot, the Tri-Star. The chassis is deployed at the exit of the container and the wheels are expandable.

Some swarms use four wheels for movement and locomotion. The omni-directional mobile robot described in [47] is equipped with four independent driving wheels equally spaced at 90° from one another. The drawback of having a wheeled robot is that, if any obstacle comes in the way of the robot, the robot may not be able to run over that obstacle. Also, the speed of a wheeled robot changes with changes in surface roughness and inclination. However, wheeled robots require little power and are energy efficient.

Tracked Swarm Robot

Tracked robots use crawl units or tracks similar to those used for terrestrial mobile applications like military tanks and automobiles. These tracks are especially suited for motion on difficult terrain. The robot Aurora Automatika in Pennsylvania, built by Hagen Schempf in 1999, consists of a single and directional track. The University of Wuerzburg built a two-tracked Nanokhod robot, with an articulated pendulum used as weight-cons and itself made of a caterpillar. It can move horizontally on slopes. The Nanokhod [48] is a miniaturized track-enabled robot that was developed based on Russian technology. The tracker consists of two "caterpillar" track units, a tether unit, and a payload cabin. The caterpillar tracks are driven by four internal drive units, each consisting of a stepper motor attached to a 64:1 planetary gear in front of a crown and pinion stage. The output stage is a miniaturized harmonic drive whose input is coupled directly to the crown gear. The omni-directional mobile robot is equipped with four independent driving wheels equally spaced at 90° from one another. The tracked robot has better traction capability on loose soil and can handle large hinder and small holes, but it is inefficient due to the friction of tracks that "scrub" along surfaces while turning.

Leg-Based Robot

Some swarm robots use legs for locomotion, but they are very complex to build and controlling the legs is also complicated. They tend to be very slow and create an impact with each step.

Hybrid Robot

A main premise behind hybrid robot architecture is that the combination of any two mechanisms is better than a single one, as it benefits from the advantages of the two. This concept is highly used in recent prototypes such as the Swarm Bot [35] and S-Bot [45]. The S-Bot is based on track and wheel combination platforms called Treels, as shown in Figs. 5 and 6. Each treel is controlled by an independent motor so that the s-bot can freely move in any environment and can easily rotate on a spot. This mechanism allows each s-bot to move over moderately rough terrain with complex obstacles. AutoBot [33] uses a differential drive with reliable motion control configured with caster

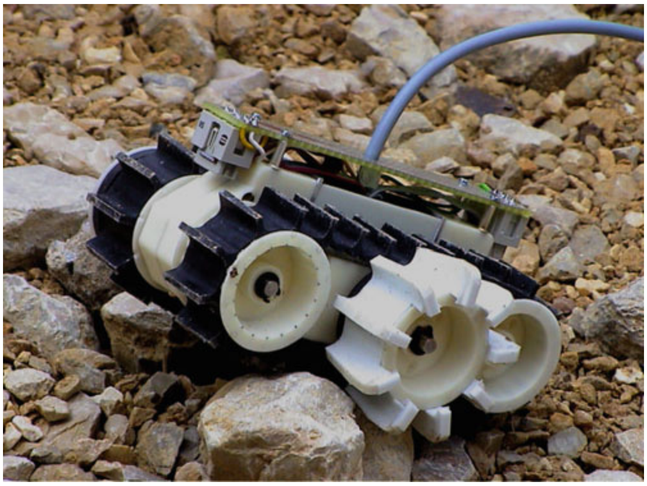

Fig. 5 S-Bot tracks [45]

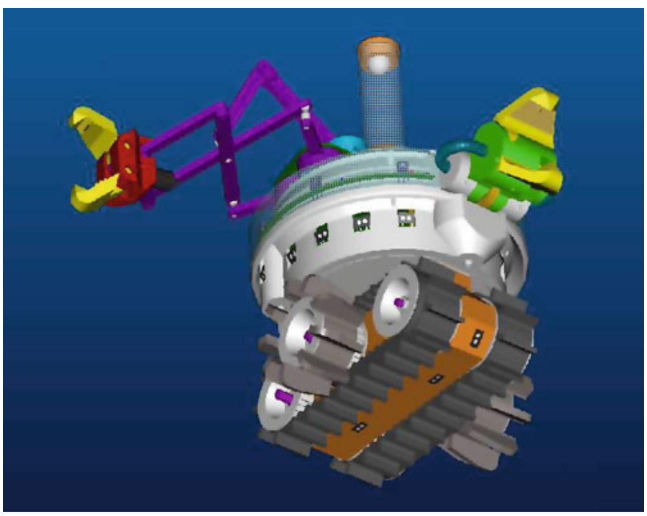

Fig. 6 Bottom view of the s-bot robot showing its independently-controlled treels (Mondada et al. 2003) (copyright @2003 Mondada et al.)

Fig. 7 Pioneer II P2AT-8 (copyright @ 2007 Pioneer Inc., et al.)

Fig. 8 Solarbotics motor and gearbox assembly used in MiLyBot [52] (copyright @ 2008 Luis Vegas et al.)

wheels and a pulse width modulation technique that is employed for DC motor control.

Piezoelectric actuators are commonly used for locomotion and actuation of mobile micro robots of a size between 1 dm^3 and 1 cm^3.

Figure 7 shows the Pioneer II P2AT-8 robots and custom-built track robot at ACE Lab, UTSA. In this module, a sonar based sensor platform is used with both four-wheeled robots and tracked robots.

Manipulation of objects by swarm robots is accomplished by grasping, pushing, and caging [49]. Grasping action includes form closure and force closure techniques. By way of example, grippers [34, 45, 48] are used as manipulators in almost all swarm robots, both for interconnection with other swarm robots and for grabbing (grasping) objects. Such grippers are usually operated by a DC motor. Opening and closing of the grippers is typically measured by means of an optical sensor. In Voyles' TerminatorBot [50], the robot consists of a cylindrical body with dual 3-degree-of-freedom (DoF) arms controlled by two gear motors that can be fully stowed inside the body of the robot. Some robots use a mechanical hook controlled by a spring return actuator to connect with other robots. Minghui et al. [51] describe a wheel-manipulator robot consisting of a triangle wheel and a 5-DOF arm with an end-effector. Other connection techniques include point-to-point and surface-to-surface attachment mechanisms. M-TRAN, CORNO and I-CUBE [19] use a surface-to-surface connection in which an active attachment-making connector extends three hooks from its mating surface to grab onto features of a passive mating connector. The passive connectors are built from two bars of stainless steel rigidly integrated in the hemisphere. These three hooks are driven by a DC motor via a worm gear. MiLyBot [52] uses a Solarbotics motor, as shown in Fig. 8. These motors exhibit low power consumption and excellent torque.

Controller and Communication Module Platform Review

In robot swarms, communication can work using any of several different techniques, depending upon factors like robot size, robot cost, budget, the environment in which the robots will work, and other application-specific limitations. Generally speaking, swarm robots are controlled by one of two broad approaches: a centralized approach where a single supervisory robot plans for the group, or a distributed approach where each robot is responsible for its own planning [53]. In recent years, robots have become more mobile, requiring wireless communication techniques like Bluetooth, wireless LAN, stigmergy, or visual signaling using IR LED's. "Stigmergy" was introduced by Pierre-Paul Grasse in the late 1950s to describe the type of indirect communication employed by insect life such as ants and termites, using pheromones to mark the shortest path back to the nest, to mark the location of food sources or to identify danger. However, communication can also be established by sending messages to other robots using Bluetooth, wireless LAN or infrared LEDs. Infrared LEDs are used in SWARM BOT; S-BOT achieves visual communication with different color LEDs and a camera mounted on the top of robot to receive signals from other robots. This technique is very economical and easy to install on mini robots or swarm robots, but sunlight or other light sources can interfere with this type of communication. Wireless LANs may used on mid-sized robots to send high-volume message traffic to the robot team, but this type of network can be disturbed by other RF-radiating devices. One of the best and most cost-effective techniques for communicating with team swarms is Bluetooth communications, which requires a unique ID for each swarm robot. There are numerous Bluetooth devices or cards available on the market [32], using both WaveLAN and Bluetooth wireless communication systems with wireless antennae.

Ming et al. [54] explored the use of wireless mesh networks (WMNs) and mobile ad hoc networks (MANETs) for robot communication with the help of mesh routers, PDA's, wireless adapters, and GPS' on each robot. In CORNO [7], each module communicates with other modules by means of an IR transmitter and receiver to form a local communication network. CORNO is controlled by a BASIC STAMP 2 processor card. M-TRAIN [29] also uses the BASIC STAMP 2 microcontroller for controlling the modules and communicating through the Relay PIC by serial communication. AUTOBOT [33] uses 2.4 GHz 1 Mbps GFSK radio-based local communication by means of a Cypress CyFi™ CYRF7936 radio integrated circuit and an integrated PCB Trace antenna. A swarm robotics project by Samanta et al. [55] at Villanova University, PA employed LEGO NXT mobile robots with Bluetooth communication via NXT bricks each containing an Atmel 32-bit ARM7 processor running at 48 MHz with 64 KB of RAM and 256 KB bytes flash memory. Communication between the NXT robots and a PC laptop host was implemented using a D-Link DBT-120 wireless Bluetooth 2.0 USB Adapter.

The Autonomous Miniature mobile Robot (AMiR) [56] uses an AVR microcontroller series as the main processor for managing all AMiR's modules. This microcontroller, an ATMEGA168 clocked at 8.0 MHz, using its internal RC oscillator and IR-based local communication for each module. In the summer of 2007, Cleveland State University [57], the square robot swarms was designed, communication between these robots and the base station is accomplished using a MaxStream 9Xtend RF transmitter/receiver and the PIC18F4520 as microcontroller with C language complier. KOBOT [58] was designed as a self-organized flocking robot using an IEEE 802.15.4/ZigBee compliant XBee wireless module with a range of approximately 20 m for communication between robots, a PIC 18F4620A microcontroller, and a PC (supervisor). There are also other commercially available low-cost microcontroller devices available such as the Arduino, which is a flexible and open source electronic platform, easy to use and easy to program in a variety of programming languages. Wireless communication can also be established using CC250 with Atmega16 built-in Universal Asynchronous Receiver Transmitter (UART).

Power Option

Another important consideration for swarm robots is the power supply, since each swarm robot is very small and highly mobile in nature, suggesting that the power supply should be small and light enough to be mounted on the robot. Most swarm robots work on 5–25 V DC power supplied by rechargeable lithium batteries. Lithium-Polymer batteries (Li-Po) [59] have several advantages in such applications, including: high energy density, thin size, and operational safety when compared to other rechargeable batteries. The ATRON swarm robot module, 11 cm in diameter, equips each module with two 3.6 V 980 mAh ion-lithium-polymer cells. This provides 7.2 V at an ampacity of 980mAh for each module. S-bot is equipped with two Lithium-ION batteries placed between the tracks. The power storage capacity of these batteries is 10 Wh.

Table 2 Advantages and disadvantages of various swarm robot platforms

Sr. No	System	References	Advantages and disadvantages
1	PolyBot	Yim et al.	Advantages: 1st system to demonstrate the ability of self-reconfiguration with most active modules in a connected system. Each module fits within the 5 cm cube. They are versatile in nature. Each module contains a Motorola PowerPC 555 processor with 1MByte of external RAM, and DC brushless motor with built in hall effect sensors Limitation: Insufficient sensory unit for mapping of environment. Cannot work in unknown environment with rough surface or when obstacle avoidance is not possible
2	M-TRAN	Yoshida et al.	Advantages: Very small actuated modules, highly-robust, miniature, and reliable. Quick self-reconfiguration and versatile robotic motion Limitations: Connection mechanism works on an internally balanced magnetic field that is not strong enough to hold the other modules. Single M-TRAN module does not have enough DOFs for switching from one posture to another form. Lack of sensors leads to mapping and control problems. Power consumption is more as uses servo motor and electromechanical force for connectivity
3	ATRON	Stoy et al.	Advantages: Each module is equipped with its own power supply, sensors and actuators, allowing each module to connect and communicate with a neighbor module. Able to sense the state of its connectivity and relative motion Limitation: Since each module includes two-axis accelerometers only, a module cannot tell if it is turned upside down or not. When two modules are connected, it's very difficult for them to move themselves, which requires cooperation from its neighbor. They are not mechanically stable and due to this mechanical instability, their electronic performance is poor
4	SamBot	Hongxing Wei et al.	Advantages: SamBot is a combination of mobile and chain-based modules capable of self-assembly and self-reconfiguration. SamBot uses 4 docking mechanisms for connecting with other SamBots. Detects other SamBots using Infrared sensors Limitation: Infrared sensors limit the search range and require line-of-sight between SamBots. SamBot architecture lacks extra actuators, grippers, and sensors for gathering information about the working environment
5	Swarm Bot (S-bot)	Mondada et al.	Advantages: Robot swarms consisting of 2–40 S-bots have been successfully demonstrated. S-bots are fully autonomous mobile robots capable of self-navigation, perception of the environment and object. Capable of communicating other S-bots and transporting of heavy objects over very rough terrain Limitations: Initial cost is high. Images and sound are the only way of communicating with other S-bots. Large number of sensors and actuators consumes power, reducing functionality and operating time
6	CONRO	Stoy et al.	Advantages: Small, rectangular self-reconfigurable swarm robot with a low price. Versatile Limitation: Uses onboard low-capacity batteries that limit the usefulness of modules. Limited sensors limit ability to sense surroundings. Only two controllable degrees of freedom
7	MiLyBots	Luis Vega et al.	Advantages: Low-cost, reliable, robust, reusable, movable, size-efficient, power sparing, wireless, dynamically programmable swarm robots Limitation: MiLyBots are not self-reconfigurable, self-assembled swarm robots. Lack actuators and connection mechanisms for physically attaching to other modules
8	I – Cube	Unsal and Khosla et al.	Advantages: I − Cubes are low cost, small lattice based swarm robot with 3 DOF Limitation: Unable to provide heavy object transport. Limited sensors. Lacks actuator mechanism

Preliminary measurements show a power consumption of for one S-bot, between 3 and 5 W, which ensures continuous operation for at least 2 h.

AutoBot is powered by an 11.1v Li-Po battery with 500mAh ampacity. CYBOTS are smaller in size, around 25 cm in length, and use a pair of Li-Po rechargeable battery as power source.

Hardware Design Challenges

The performance of any machine or inter-operable group of machines is highly dependent on hardware architecture, that is, on the overall mechanical and electronic control design and structure. Over the past two decades, numerous hardware architectures have been designed and developed for self-reconfigurable, self-replicating and self-reassembling swarm robots. Each structure has focused on a different set of factors such as: flexibility, degrees of freedom, torque to weight ratio, power consumption, cost, size, control mechanism, etc. However, there are some fundamental inherent limitations imposed by various architectures that can have a profound effect on how control and manipulation of autonomous mobile swarms is accomplished. These architectural limitations can affect the precision of robot movement, robot strength, and the ruggedness of docking interfaces between modules. Motor power, power management, and the speed with which individual modules can move are also limiting factors on the performance of swarm reconfigurable robots.

Table 2 below lists a number of swarm robot systems, along with their advantages, disadvantages and limiting factors.

In the table above, all of the swarm robot systems are homogeneous except S-bot, in which the swarm robots are heterogeneous.

Conclusion

In this survey, we have outlined a number of aspects of swarm robot hardware architecture, focusing on the types of interactions that can occur in such systems, including self-reconfigurability, self-assembly and self-replication. To explore the challenges related to swarm robot systems, we have outlined a general classification framework for considering the various design and protocol aspects that can be used to develop specific applications of swarm robotics. One of the challenges that faces swarm system designers is the selection of an appropriate swarm architecture to best address the specific constraints of their application in real world. Cost and miniaturization/size are always extremely important factors for swarm robots.

In our future work, we will design and build a medium-powered hybrid mobile swarm robot system that is cheap enough to mass produce. Numerous researchers have faced and described significant challenges, and while some have made some progress to overcome these problems, there is still considerable work to be done.

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Internet and Transdisciplinary Based Teamwork Formula for Elaborating a Bachelor's or a Master's Thesis

Liciniu A. Kovács and Mihai F. Talpoş

Abstract

The last step in a student's schooling experience is the presentation of his/her bachelor's or master's thesis. This constitutes a good opportunity for the students to "show off" their capabilities, their individual performances related to the theme of the thesis, and the amount of knowledge that they have accumulated over their years of study in a higher educational institution. Such reality has fueled an important question across the educational system of whether it is enough to expect that from a bachelor's or master's thesis, or it is time to change the methodology of thesis elaborating by implementing new methodologies. The paper examines possible methods that aim to shift from the traditional way of writing a bachelor's or a master's thesis to a modern approach, based on national/international teamwork. Such a method would include intensive usage of the Internet for information, documentation and collaboration, and would also valorize the methodology of transdisciplinarity. The discussion begins with the explanation of the major challenges that students with different majors, cultural, religious, and ethnic backgrounds face when they attempt to write a good thesis. This is followed by arguments that support the idea of teamwork. The paper finally concludes with examples of actions that will help academic authorities to implement such a new, complex and innovative methodology. The authors intend to turn this article into a good starting point for a pilot project, which aims to create a partnership between several universities/entities that are ready to embrace and implement this initiative.

Keywords

Bachelor's thesis • Master's thesis • Teamwork • Transdisciplinarity

Introduction

"So what is a thesis? It's a masterpiece! . . ., It's a lots of cool coding surrounded by some boring text!, It's a research report! It's yet another hurdle to graduation! . . . A thesis is a communicative act from you to the person who is grading it" [1].

Unfortunately, for most of the students, writing a bachelor's or a master's thesis is a curse, when it should actually be perceived as a blessing. The "neophobia" (fear of the new) induced by the thesis stage in the academic life of a student is in fact normal, given the complexity of the process.

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_59,

Choosing the right adviser, selecting a good/acceptable topic, planning how to do the work, doing the actual research, and finally writing the paper in a disciplined manner are all stressful stages in the process of elaborating a good bachelor's or master's thesis.

The Ideas

Such theses usually contain theoretical and/or applicative knowledge in regard to different majors, and therefore they are, by definition, "multidisciplinary", "pluridisciplinary", or even (sometimes) "transdisciplinary". The conclusion emerges naturally: theses must go beyond the actual limitation of the concept, by embracing the idea of teamwork. In terms of teamwork, good models are found in private initiatives like:

- NEF (New Economics Foundation) which "works with all sections of society in the UK and internationally—civil society, government, individuals, businesses and academia—to create more understanding and strategies for change" [2].
- The Nordic Entrepreneurship Monitor, where it is stated: "The founders of the company and the management team are crucial for building a successful company. Moreover, the ability to complement internal skills with external knowledge and skills (by absorbing highly-experienced human resources to fill key positions) is imperative for the success of the firm. The learning process for these people by working with customers and developing the product and business idea is also crucial" [3].

One of the best models can be found at the Chalmers School of Entrepreneurship in Gothenburg, Sweden, where, under "The Challenge" topic, it is stated: "The mission to develop entrepreneurs and technology ventures, today is carried out in cooperation with idea providers from academic research and R&D departments at major firms. Together we work to transform promising ideas and research projects into thriving high-tech businesses, and through this reality-based approach we educate entrepreneurial leaders fit for running start-ups as well as business development in established firms.

The key to this innovative value creation is the students and the teams they form during the educational process. By acquiring the knowledge, tools and skills needed to shape the future of technology ventures and projects, and by being allowed to apply their creativity in real hands-on projects the students create real value as well as develop their entrepreneurial ability through a true "learning-by-doing" pedagogy" [4].

From another perspective, "The teaching of IT, entrepreneurial and citizenship skills is fundamental for preparing young people for today's job market, but, in general, schools are still paying insufficient attention to these transversal skills compared with basic skills in literacy, mathematics and science. Part of the problem is rooted in difficulties with assessment" [5].

If educational systems endorse the idea that a bachelor's or a master's thesis is not necessarily an individual task, but rather a team effort, in the context of disseminating educational activities that are indeed transdisciplinary, writing a bachelor's or a master's thesis can once again become a blessing in the eyes of students.

The facilitation of dialogue and exchange of ideas among students who share common, or even different academic interests could add great value to the process of writing theses that are infused with both scientific and practical substance.

A teamwork approach also helps in better using the students' inventiveness and creativity, because any contribution should be welcomed, sustained, and encouraged by the adviser. Thus the students will gain extra confidence in their knowledge, because they will receive recognition, appreciation, and respect from the rest of the team members.

These are important steps towards excellence, without any of the compromises and conditionings that the old approach involved. This new "teamwork formula", if meticulously implemented, has great valorization potential, because it helps in "capitalizing" on any innovative information or successful element for a thesis that meets the right conditions for becoming a real "masterpiece".

In this context, it is obvious that the first condition for achieving such an objective is to upgrade the current structure of Romanian public higher education. "Providing expertise to all those interested in implementing public transdisciplinary education methodology, in forming transdisciplinary attitudes among teachers and students in Romanian pre-university education" (Basarab Nicolescu [6]) should be a priority for the policy makers at the Ministry of National Education. As a consequence, the International Colloquium entitled "Transdisciplinarity in Primary, Secondary and High School Education", which took place in Arad, Romania, on the 15th of November 2012, underlined the importance of changing the vision in regards to the elaborating of bachelor's or master's theses. On this occasion, Mirela Mureşan transmitted to those interested that:

- "This major event organized in Arad represents the very first attempt to discuss (debate upon) the implementation of transdisciplinary education in the Romanian primary, secondary and high-school education. It is the first colloquium on the topic organized in Romania and it is expected to have both national and international impact, due to the participation of the academician Basarab Nicolescu, president of the International Center for Transdisciplinary Research and Studies in Paris (C.I.R.E.T., www.ciret-transdisciplinarity.org)" [7].

- "The Colloquium entitled "*Transdiciplinarity in Primary, Secondary and High-School Education*" aims at a basic establishing of a working team, at a national level, able to provide hands-on solutions for implementing the transdisciplinary education in the Romanian educational system and, moreover, for a future curriculum design guidance" [8].

So, it's time to realize that, in the short run, Romanian universities will have students with transdisciplinary education, and some of the topics taught will move from theory into practice. In fact, the large majority of the papers presented to the above mentioned Colloquium were oriented towards providing practical solutions.

In the same context, it is good to know that the C.I.R.E.T. website has a page "full" of valuable transdisciplinary Ph.D. theses. We just want to mention some of the theses presented in 2012 and 2011 [9]:

- Cantemir Mambet, *A Transdisciplinary Approach to the Management of Risks and of Decision Making Processes*;
- Maria Lucia Mureşan, *A Transdisciplinary Model of Communication*;
- Janez Cerar, *Transdisciplinary Sustainable Development*;
- Dana Lăcrămioara Oltean, *From Esthaetical Competence to Transcultural Competence: the Transdisciplinary Approach in Didactics of the French Language-Culture*;
- Frédéric Paul Rey, *Le jonglage et les sciences—D'une é tude pluridisciplinaire à une vision transdisciplinaire*.

We can easily notice that the topics of the above Ph.D. theses are very diverse, and there is virtually no limit to the transdisciplinary approach. If we take into consideration that there already exists a tendency to apply transdisciplinarity in primary, secondary and high school education, the transdisciplinary territory of higher education seems only partially covered. The Internet and transdisciplinary based teamwork formula for elaborating a bachelor's or a master's thesis presented in this paper will fill some of the gaps.

Thus, the Romanian Ministry of National Education, has to set a new objective: to enable and regulate the legal framework to allow *some* theses to be written/elaborated by teams and in a transdisciplinary approach. In this way, graduates who choose this manner of finalizing their studies will have the following advantages:

- The diversity of approaches, because the team could consist of future graduates from the same major, and also from different majors, different colleges, or even different universities from different countries. Furthermore, this will help "To foster interchange, cooperation and mobility between education and training systems . . ." [10]. Added to this diversity of approaches is also the fact that students from different majors can bring different sets of learned skills to the team, which would enrich the final result.
- Better objectivity in choosing the theme of the future thesis, because the theme can be suggested by:
  - A mentor;
  - One or more teachers;
  - A representative of a company from the local economic environment (who might be a member of the enlarged council of the educational institution, or associated in another way with such institution);
  - One of the members of the future team;
  - Scholarly articles assigned as readings in previous courses;
  - Subjects learned in previous courses along the students' academic career;
  - Books read outside the assigned academic readings, which are deemed suitable as thesis subject by the university;
  - An idea from a person, or the Internet.
- The vocational based approach, because each team member should be encouraged to contribute to the elaborating of the thesis with the aspects that he/she enjoys most. This means valuing the claim of Malcom S. Forbes: "The biggest mistake people make in life is not making a living at doing what they most enjoy" [11].
- The common participation for the benefit of the group, because the entire team may sign an agreement that, upon the successful completion of all the aspects of the thesis, the finished work would bring some benefit to the graduates.
- The acquiring and sharing of practical skills, because the entire team will learn at least the basic notions of project management, such as initiating, planning, executing, monitoring and controlling, and closing. As a checklist, a good idea is to use Rita's Process Chart [12].
- The acquiring of entrepreneurial skills, because the team members, due to their experience of working with others in the thesis team, will be able to integrate more easily and quickly in the labor market. In this sense, for non-business oriented education "we need to develop a more entrepreneurial culture, starting with young people and from school education" [13].
- The full understanding of transdisciplinary methodology, which "comprises three, some say, four axioms: multiple Levels of Reality (ontology), knowledge as complex and emergent (epistemology), the Logic of the Included Middle (Nicolescu), and integral value constellations (axiology)" [14].
- "Transdisciplinarity complements disciplinary approaches. It occasions the emergence of new data and new interactions from out of the encounter between disciplines. It offers us a new vision of nature and reality. Transdisciplinarity does not strive for mastery of several disciplines but aims to open all disciplines to

that which they share and to that which lies beyond them." [15].

- "Transdisciplinarity doesn't mean preserving distinctions, but instead integrates them in a cognitive model and places them in relation to one another" [16].

Under the effect of transdisciplinary methodology, research methods also have to be adjusted and further developed, because cross-disciplinary teams have the ability to substantially enrich the way that academic studies are done, in a manner that can be, indeed, oriented towards creating concrete/real life solutions. Thus, the research outputs will be concerned both with quality (in terms of validity and reliability of evidence), and with usefulness in the practice.

Supposedly, an appropriate team thesis writing methodology will reduce the length of time in which studies and theses are done, without compromising the quality of the results. This is because a cross-disciplinary approach will be able to bring greater uptake and use of research evidence, as a result of changing the information seeking behavior as well as the information testing behavior.

Efficiency, in a cross-disciplinary or even cross-cultural team, depends on how professional responsibilities and roles are set. Thus, while setting up such roles and responsibilities, the head teacher/teachers of a cross-disciplinary team has/have to be seriously inclined to effectively engage with the research team in determining the right priorities and the right strategies that would enable the team members to make proper use of the research evidence. This is quite a challenging task given the fact that due importance has to be given to the self expectations of each and every team member, in order to keep them motivated.

Besides that, it is also important to underline the fact that the implementation and use of transdisciplinary methodology in teaching and educational activities implies consistent investments in the so-called "virtual technology", because this kind of technology offers a proper support for good communication between the members of a team, especially when the team is an international one.

The Internet has already made an important difference in the way education is being done all over the world. It clearly offers great potential for more effective and efficient communication between the members of a research team, and it also facilitates the delivery of the research results to the teachers.

Because of the Internet, many teachers are now able to disseminate to their students targeted and pre-digested research evidence, in the context of evolving from a one-to-one communication method to a much more effective one, which implies the use of electronic networks or even professional discussion groups. Thus, teachers can present the relevant information in a format that is both easily digested by the students, and attractive. Internet based communication channels allow the transmission of clear text messages, which can be short, succinct, and concentrated on key terms and concepts. Such communication increases the chances that the students will read and understand the research information and evidence.

This brings us to an important argument in favor of the "Internet and transdisciplinary based teamwork formula", because such a formula implies the possibility of changing the students' perceptions in regard to the lack of time during a study day to process and assimilate large quantities of information. From the students' perspective, Internet based communication channels are probably the most convenient and effective methods to access an appropriate range of information sources that are absolutely necessary in a research project, and, even more important than that, they have the skills to do it. In this sense, a good example comes from Daphne Koller:

- "Students collaborated in these (online) courses in a variety of different ways. First of all, there was a question and answer forum, where students would pose questions, and other students would answer those questions. And the really amazing thing is, because there were so many students, it means that even if a student posed a question at 3 o'clock in the morning, somewhere around the world, there would be somebody who was awake and working on the same problem. And so, in many of our courses, the median response time for a question on the question and answer forum was 22 min. Which is not a level of service I have ever offered to my Stanford students.
- And you can see from the student testimonials that students actually find that because of this large online community, they got to interact with each other in many ways that were deeper than they did in the context of the physical classroom. Students also self-assembled, without any kind of intervention from us, into small study groups. Some of these were physical study groups along geographical constraints and met on a weekly basis to work through problem sets. This is the San Francisco study group, but there were ones all over the world. Others were virtual study groups, sometimes along language lines or along cultural lines, and on the bottom left there, you see our multicultural universal study group where people explicitly wanted to connect with people from other cultures" [17].

This experience should be taken into consideration for elaborating bachelor's/master's theses.

In the same context of intense usage of the Internet "… if we could offer a top quality (online) education to everyone around the world for free, what would that do? Three things:

- First it would establish education as a fundamental human right, where anyone around the world with the ability and the motivation could get the skills that they need to make a better life for themselves, their families and their communities.
- Second, it would enable lifelong learning. It's a shame that for so many people, learning stops when we finish high school or when we finish college. By having this amazing content be available, we would be able to learn something new every time we wanted, whether it's just to expand our minds or it's to change our lives.
- And finally, this would enable a wave of innovation, because amazing talent can be found anywhere. Maybe the next Albert Einstein or the next Steve Jobs is living somewhere in a remote village in Africa. And if we could offer that person an education, they would be able to come up with the next big idea and make the world a better place for all of us" [18].

Again, this experience should be taken into consideration for elaborating bachelor's/master's theses.

It has been mentioned that in a transdisciplinary approach, cross-cultural/international teams can be formed in order to elaborate really valuable bachelor's/master's theses. The main advantage of forming an international team is the fact that the thesis will benefit from the differentiation and peculiarities brought by the national specifics of each member of the team. In this sense, we already know that "By now, most business schools have embraced the idea of enrolling 30–40-year-old managers in specially designed EMBA programs. But what about the growing number of people in their 1950s, 1960s, or even 1970s who embrace new professional challenges after decades of work experience?" [19]. International teams will be easily formed with such experienced people with different cultural, religious, ethnic background, and directions of study.

The advisors of such international teams should support the combining of different national perspectives in the final form of the bachelor's/master's thesis. This constitutes a good premise for obtaining a final result that has international relevance, in a world that is heading towards globalization.

As stated above, the transdisciplinary approach brings obvious advantages. However, it is important to give just as much attention to the stumbling blocks that might appear in transdisciplinary practice. Although many of the blocks of transdisciplinary practice have already been suggested in the lines above, we briefly qualify some of the causes of these stumbling blocks, and postulate some of the effects that they might have [20]:

- The risk of "purely symbolic participation"—positions, roles and contributions can be consistently different in a transdisciplinary team. The different resources made available by the team members, in the participatory processes of transdisciplinary teamwork "can lead into diffuse all-inclusive" results of the collaboration, if the final studies/theses embody different contributions that are not transparently presented.
- The difficult integration of the theoretical frame-works and of the applied models in the transdisciplinary study—a transdisciplinary research project has to integrate the perspectives and knowledge of various disciplines and stakeholders. As a result, "collaborative efforts of integration" have to be made in order to obtain practical common outputs in a teamwork research project.
- The "differing and often conflicting values of participating team members"—the value dimensions of transdisciplinary collaboration may turn out to be one of the most important stumbling blocks in the transdisciplinary practice. Such uncertainties may lead to very "diffuse and disputed outcomes", or (even worse) to over-generalized and over-interpreted research results.
- The complex and overloaded "management and leadership of a transdisciplinary endeavor"—the management and leadership of transdisciplinary processes usually include a range of partners and institutions. This is heightened by the fact that the control system of the team members and participating researchers is anchored within their home institutions rather than in the transdisciplinary team. As a result, the management of transdisciplinary research teams has to deal with the "squeeze between high internal and external expectations and the low formal steering powers".
- The difficulty of "external evaluation and internal quality control of transdisciplinary research" projects. The lack of internal quality control may lead to poor research outputs, which would equal the discrediting of the transdisciplinary team. As a result, it is quite a challenge for the team members to find a delicate balance between respecting specific competence, and overstepping them in constructive though critical dialogues.

Before modernizing its educational system by implementing transdisciplinary methodology, Romania should take a look at other European countries that have already experimented with such formulas. This way, Romania might arrive at the conclusion that nothing has to be invented, and this might constitute an opportunity to skip several evolutionary stages. However, Romania should adopt the foreign methods in a creative way, taking into account its national specific. By doing so, bachelor's/master's theses in Romanian universities (and in other universities from other countries as well) will stop being just a "showoff".

A New Project

This paper's main idea allows a new educational project to flourish. For such purpose, an initiative group that includes Babeş-Bolyai University, Cluj-Napoca, Romania; Vestfold University College, Tønsberg, Norway; Christelijke Hogeschool, Ede, the Netherlands; Emanuel University of Oradea, Romania; The Romanian Association for Informal Education (NGO); Ensyro Ltd.; CSi Romania Ltd.; and Commodo PrestServ Ltd., has already been formed as a result of the availability of grant funding, the publication of scientific reports, and the desire to enhance a long-term partnership based on this idea.

Objectives of the New Project

- Develop one particular model that will determine the shift from the traditional way of elaborating individually bachelor's or master's theses to a modern, innovative approach, based on national/international teamwork.
- Conduct at least four bachelor's theses and one master's thesis, based on the new procedure involving national/international teamwork.

Target Groups

- Students with different majors, cultural, religious, and ethnic backgrounds from Babeş-Bolyai University, Emanuel University, Vestfold University College, and Christelijke Hogeschool;
- Students from other public/private Romanian and foreign higher education institutions interested in experimenting the teamwork formula in order to elaborate a bachelor's or a master's thesis.

Main Activities

- Initiate the new methodology, uncover initial requirements and risks, and suggest improved regulations so that *some* theses can be elaborated based on national/international teamwork.
- For each team of candidates: create measurable objectives, clearly identify stakeholders, create activity lists, develop schedules, determine all roles and responsibilities, plan communications, and determine the best ways/procedures to take the final examinations.
- Disseminate (via joint conferences, workshops, industrial partners, web) knowledge, experiences, methodologies, and tools.

Learning Outcomes

- Acquiring and sharing practical skills;
- Acquiring entrepreneurial skills;
- Gathering experience working in an international, multicultural setting.

Expected Outputs

- A coherent model for creating more understanding and strategies for change and diversity in the educational system.
- Better cooperation between higher education institutions, companies, and the labor market.

Expected Impact on the Participants

- Extended experience of work/collaboration in an international virtual environment, since most of the communication will be online.
- Ability to understand more easily the cultural aspects of partner countries.
- Improved language skills.

Expected Impact on the Participating Organizations

- Increased capacity to organize bachelor and master thesis projects across the participating universities.
- Improved regulations in universities that will allow *some* theses can be elaborated based on teamwork.
- Partner companies and universities can test the use of international teams in a real setting.

Expected Impact on the Estimated Target Groups

- Students will be more interested in teamwork.
- Graduates will meet a demand in the labor market.

We expect that the logic and operational model developed and applied in this project will be extended to the elaboration of Ph.D. theses and, later on, will evolve by including the transdisciplinary approach/paradigm.

Conclusion

The above described approach/methodology (Internet and transdisciplinary based teamwork formula for elaborating a bachelor's or a master's thesis), which can obviously be improved, has four types of beneficiaries:

- universities at institutional level,
- teachers at individual level,
- graduates at competencies level,
- local and global economic environment at the quality level of the employees.

Consequently:

- Universities can select from among the best graduates, who will be able to work in teams, using Internet and transdisciplinary approaches, on research projects.
- Teacher advisors will be encouraged to be up to date with news in their field of activity, and other related areas.
- Graduates can easily earn transversal competencies, which are geared towards finding innovative, creative solutions, and direction for having their own entrepreneurial initiative.
- The local and global economic environments will more easily find/discover "well-rounded" educated employees with team approach in their mind, and with a vision of performance.

Workforce mobility is a goal of, but not limited to, the European Union. Employees with multicultural experiences are in demand. Therefore, there are many reasons why collaboration on bachelor/master theses should not only be tried out, but be established as a permanent offering.

Acknowledgment We are grateful to Mr. Lasse Berntzen for his support and to Mrs. Monica L. Popescu for revising this paper.

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A Dynamic Pricing Algorithm for Super Scheduling of Computational Grid

Reihaneh Bazoubandi and Fatemeh Abdoli

Abstract

In this paper, we propose a dynamic pricing strategy which is based peer-to-peer grid computing used for a SLA_based super scheduling and greedy backfilling resource allocation mechanism. Our goal is making load balancing in the overall grid system, by changing the value of resources. Without any pricing policy in grid, because of increasing load of cheaper resources and lack of demands for expensive resources, system will be out of balance.

In this paper, our attention is towards the load factor in the overall system and the load factor on each resource. The rates of demand and supply for each resource are two other criteria for overall system price balancing in system. If the price of a resource is high its demand becomes low hence a price adjusting algorithm must be active to insure acceptable utilization of resources. On the other hand is the price of a resource is low it will receive many demands which in turn will increase the turnaround time of the requests. These algorithms are developed in this research and the overall effectiveness of the algorithm is evaluated. In result, we almost receive balancing state at overall system.

The key advantages of our approach are (1) increase in the total earning of resource owners and users, (2) increase in the number of resources being used, (3) increase in the number of accepted jobs, and (4) decrease in the rate of budget spent of users.

Keywords

Dynamic pricing • Load balancing • Resource allocation • Service level agreement

Introduction

A grid enables aggregation of topologically distributed scientific instruments, storage devices, data, applications and computational resources. The resources in the Grid are heterogeneous and geographically distributed. Availability, usage and cost policies vary depending on the particular user, time, priorities and goals. The management of resources and application scheduling in such a large-scale distributed environment is a complex task [2].

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The Grid super scheduling [22] problem is defined as: "scheduling jobs across the grid resources such as computational clusters, parallel supercomputers, desktop machines that belong to different administrative domains". Super scheduling in computational grids is facilitated by specialized super schedulers such as Grid Federation Agent, NASA-Super scheduler [7], Nimrod-G [9], and Condor-G [10]. Super scheduling activity involves (1) querying grid resource information services (GRIS) for locating resources that match the job requirements; (2) coordinating and negotiating SLAs; and (3) job scheduling. The grid resources are managed by their local resource management systems (LRMSes) such as Condor [11], PBS [12], SGE [13], Legion [14], Alchemi [15] and LSF. The LRMSes manage job queues, initiate and monitor their execution.

T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_60,

These systems treat all resources with the same scale, as if they worth the same and the results of different applications have the same value, while in reality the resource provider may value his resources differently and has different objective function. Similarly the resource consumer may value various resources differently depending on its QoS based utility functions, may want to negotiate a particular price for using a resource based on demand, availability and its budget.

Also, we used service level agreement, SLA, in this environment. A SLA is the agreement negotiated between a super scheduler and LRMSes about acceptable job QoS constraints. A SLA-based cooperative job super scheduling approach has many advantages: (1) It inhibits super schedulers from submitting unbounded amounts of work to LRMSes; (2) once a SLA is reached, users' are certain that agreed QoS shall be delivered by the system; (3) job queuing or processing delay is significantly reduced, thus leading to enhanced Qos [1].

In this work, we propose a dynamic pricing model, while allocating jobs to resources. At first a cluster's owners assume a primary price for itself. By attention the issue economic mechanism and load balancing of system, it is impossible to attach load balancing, by only assume primary price, without attention to rate of demand and supply of resources.

Because each resource determines its price just based of its supply and power, and ignores the budget and power of customers, also, the ability and price of other resources.

At result, in allocating, some resources have no accept or very low accept, while they are low load. But other resources have many demands, while they are over load. And this problem cause very low load balancing.

The advantages of our dynamics pricing are: (1) increasing the payoff function of resource owners (2) increasing the rate of using the resource in grid (3) the Number of accepted jobs grows up. (4) The budget spent of user grows down. Generally, increase the predefined QoS of users. (5) In allocating jobs, almost attach to estimate balancing of the resource's price in grid.

Related Works

In this section, we briefly summarize Grid super scheduling approaches that apply a SLA-based or a negotiation-based job super scheduling process and if those models use of pricing policy present it.

The work in [1], proposes greedy backfilling for allocating resources to jobs and SLA used for super scheduling. It is also, background of our work. Improving in this article in comparing previous works is using Greedy backfilling method, for scheduling resources, which allow to resource owners, decide about allocating resource and increasing the it's payoff function.

In this model, the resource owners configure the resource access cost ci, remain static throughout the simulation. In real, resource's pricing is only based on supply and acceptation rate. This isn't desired, because the demand to expensive resource decreases, in compare of cheaper resources. According to SLA model, resource doesn't accept jobs, when they can't satisfy deadline, in result, drop rate increase. However, there are some resources in grid that are not busy in desired intervals, but because of high price haven't any supply and any utilization, and it cause low earning for resources owners. Specially, for expensive resources it is.

The work in Ouelhadj et al. [3], proposes a multi-agent infrastructure that applies a SLA protocol for solving the Grid super scheduling problem. The SLA negotiation protocol is based on the Contract Net Protocol. The system models three types of agents: a User agent (UA), a Local Scheduler agent (LSA), and a Super scheduler agent (SSA). The UAs are the resource consumers that submit jobs to the SSA for execution on the grid platform. The LS functionality is similar to our LRMS-managing job execution within an administrative domain. The LSA obtains jobs that are submitted by local and remote UAs. The SSA agents are responsible for coordinating job super scheduling across different site in the system. In this work doesn't consider site autonomy issues.

Tycoon 2004 [4] is a distributed market-based resource allocation system. Job scheduling and resource allocation in Tycoon is based on a decentralized isolated auction mechanism. Every resource owner in the system runs its own auction for its local resources. Furthermore, auctions are held independently, thus lacking any coordination. Tycoon relies on centralized Service Location Services (SLS) for indexing resource auctioneers' information. Auctioneers register their status with the SLS every 30 s. Application level super schedulers contact the SLS to gather information about various auctioneers in the system. Once this information is available, the super schedulers issue bids for different resources (controlled by different auctions) constrained by resource requirement and available budget. In this setting, the super scheduling mechanism clearly lacks coordination. Auctioneers determine the outcome by using a bid-based proportional resource sharing economy model. In contrast: our used super scheduling approach is based on decentralized markets.

The work in Subramani et al. [5] presents a grid super scheduling technique based on a multiple job SLA negotiation scheme. The key factor motivating this work is redundantly distributing the job execution requests to multiple sites in the grid instead of just sending a request to least loaded one. The authors argue that placing a job in the queue at multiple sites increases the probability that backfilling strategy will be more effective in optimizing the scheduling parameters, which includes resource utilization and job average turn around time. In other words, the scheduling parameters are system centric. The LRMSes at various grid sites apply the FCFS policy with Easy backfilling approach for resource allocation.

Butt et al. [6] presents a super scheduling system that consists of Internet-wide Condor work pools. Shan et al. [7], models grid super scheduler architecture. And finally, Yeo and Buyya [8] propose SLA based cluster resource allocation. The SLA acts as a contract between the end-user and the cluster provider whereby the provider pays the penalty amount if the negotiated SLA is not satisfied.

But our used model in compared of all previous models has these advantages: (1) The SLA parameter includes the users' deadline, budget and timeout (the total amount of time super scheduler is willing to wait before SLA agreement is reached). (2) We apply a Greedy backfilling approach at grid sites for maximizing resource owner payoff function. (3) We consider one-to-one SLA coordination mechanism for super scheduling, hence largely limiting the network communication overhead; and (4) our approach incorporates a dynamic pricing method for load balancing of system.

On the other hand, there are many systems have attempted to apply the concept of computational economy for information management, CPU cycles, Storage, and Network access. They include Mariposa [11], Mungi [12], Popcorn [13], Java Market [14], Enhanced MOSIX [15], JaWS [19], Xenoservers [16], D'Agents [17], Rexec/Anemone [20], Spawn [18], Mojo Nation [21]. Almost, all of these systems have been designed with a specific goal in mind either for CPU or storage management. In order to use some of these systems, applications have to be designed using their proprietary programming models, which is generally discouraging, as applications need to be specifically developed for executing on those systems [2].

Existing economy models are auction or commodity market based. The auction base mechanism is one to many or many to many relations. Then, they are unusable for peer-to-peer systems. Therefore, we can just use pricing models based on commodity market. The available commodity market model that used for grid computing is more efficient than auction based models. However, they are very complicated to apply. For example, Wolski et al. [23] uses high-degree polynomials to capture excess demand behavior and reach to balanced state. He uses 17° polynomial for doing calculation, that order time is high and complex.

Therefore, we want to introduce a new dynamic pricing algorithm, which used for P2P systems and is simple to apply.

Our Proposed Work

The background of our proposed method is [1]. According to that method for each job, the GFA bids for SLA contract on the fastest resource. This resource must reply at most until negotiation delay. After delay or if this resource has too much load or the SLA bid does not fit the resource payoff function, the bid eventually timeout.

On the other side, resource owner has queue of SLA bids. Every incoming SLA bid is added to the LRMS request queue. The LRMS scheduler sorts and iterates through the SLA bid queue of the following events occur: new SLA bid arrives to the site; job completion or SLA bid reaches its expiration time.

Therefore, the GFA checks SLA parameters of job, such as deadline, number of required processors [1].

If resource owner is over load or hasn't sufficient processor for completing job until the determined deadline, the job's GFA undertakes SLA contract negotiation with the next available contractor in the net. Otherwise, if accept these conditions within the bid time, then the resource owner and job's user negotiate about the acceptable contract price.

Here, we assume that user shares her available budget between her jobs, in the ratio of the job's lengths, this means, if one job has more length, gets more budgets. Also, user's budget usually is logical and sufficient for doing her jobs. If numbers of jobs are many, available budget is more and vise versa.

After that one job removes from lists of user's jobs, again the remaining budget is divided between the other remaining jobs.

Therefore, resource owner based on currently price and job length calculates excepted cost for doing job or paying cost. This cost is compared to job's budget, and then based on load on resource, or it is calculated new price for resource and job assigned to it, and or price of resource doesn't change and resource owner doesn't accept job.

Negotiation starts between resource owner and user for price rate. If resource is overload and job's budget is more than suggested resource owner's price, resource's price has increased and vise versa if resource is under load or even free load and job's budget is less than suggested resource owner's price, resource's price has decreased. This method is used for all demand in system. Therefore, if one job has very high price, and it causes increasing one resource's price, other job's prices almost balance resource's price.

For calculating resource's work load do following stages: at first, in current state system, for each job i, that it is resident on resource j:

$$T_{residij} = deadline_i - \left(T_{submitij} - T_{enteri}\right)$$

Where $deadline_i$ is the total time that job i has for execution, T_{enteri} is the time when job i is enter to system and $T_{submitij}$ is the time when job i is submitted into the cluster j. at result, $T_{residij}$ is the duration that job i is resident on resource j. if the required time to execute job i be T_{execi}, therefore, for each job i, the time that resource j is busy equivalent to $T_{execi}/T_{residij}$. And if we have n jobs on resource j, the busy time value is calculated for each job, and then we add all of them.

$$Load\_fraction_{ij} = \frac{T_{execi}}{T_{residij}}$$

```
If (loadFactor_Ri < System_load_factor)
{
  If (resource_i_Cost (job_j) > job_j.Budget)
  {
  new_cost_Ri = (-Δ load_factor_Ri /2) ×job_j.Budget +
                        (1+ (Δ load_factor_Ri /2)) × resource_i_Cost (job_j)
    }
  }
  Else if (loadFactor_Ri > System_load_factor)
    {
    If (resource_i_Cost (job_j) < job_j.Budget)
     {
        new_cost_Ri = (Δ load_factor_Ri /2) ×job_j.Budget +
                        (1-(Δ load_factor_Ri /2)) × resource_i_Cost (job_j) ;}
```

$Load\_fraction_{ij}$ is equivalent to load fraction of job i on resource j with 1 MIPS power.

Also, for m resources in system, we have many different processing powers and for compare between load and Resource's busy time; we must translate them to the same unit and compare them at same condition.

We have one type unit, for each type of resources (CPU, memory, printer, etc.) in grid. Therefore we compare each resource with the same type resources.

For example, the unit for CPU is MIPS (Million Instruction Per sec). We translate the busy time of each CPU to one MIPS, so that it is the same for all resources. Then, for calculating the load factor on resource Rj at current time, we use of following rate:

$$Load\_factor_{Rj} = \frac{\left(\sum_{i=1}^{n} load\_fraction_{ij}\right)}{MipsRating_{Rj}}$$

$Load\_factor_{Rj}$ is load on resource j with for n jobs and $MipsRating_{Rj}$ is the rate of speed on resource j.

For investigate the status of resource j in system, whether it is under or over loading, we must calculate the average load work factor of overall system for each MIPS, and compare it to $Load\_factor_{Rj}$.

We assume this value for average system load:

$$System\_Load\_factor = \frac{\sum_{j=1}^{m}\left(\sum_{i=1}^{n} load\_fraction_{ij}\right)}{\sum_{j=1}^{m} MipsRating_{Rj}}$$

System_load_factor is almost balanced load factor for m resources in system and n jobs on each resource. This means, if one resource has the same load factor with system load factor, it is almost at balanced state. A resource's load factor less than system load factor, we named under or free load resource and a resource's load factor more than that is over load resource.

If one resource's load factor is very far than system load factor, this resource is very far than balanced state and vise versa. Therefore, we calculate $\Delta load\_factor_{Rj}$ as the following:

$$\Delta load\_factor_{Rj} = Load\_factor_{Rj} - System\_load\_factor$$

In addition, in our model the owner resources make decision about accept or reject jobs. At first, each resource checks the number of its available processors and if it is ok, accept the job. Therefore, in our system it is impossible that load factor of one resource become more than 1. At result, system load factor always is less than 1.

The last stage, is calculating the new price of resource, depending on its status in system.

This is a part of Suggested algorithm:

In above algorithm, the coefficient of job's budget is $|\Delta \text{load\_factor}_{Ri}|/2$. Because, whatever $|\Delta \text{load\_factor}_{Ri}|$ be larger, the effect of job's budget must be more and vise versa.

Dividing load factor on two in job's coefficient is for that reason that, the effect of job's budget must be lower than resource cost. We must change the resource price and job's budget, at most and at least just same the average of user's price and resource' price. Because of, the goal and constrains of resources owners and users, that the resource proposed price shouldn't change more than 50 %, because it is a very dramatically change.

In this algorithm, by changing $|\Delta \text{load\_factor}_{Ri}|$ from 0 to 1, the job's budget coefficient changes from 0 to 0.5 value and resource's cost coefficient changes from 1 to 0.5. At result, job's budget has direct ratio with $|\Delta \text{load\_factor}_{Ri}|$ and resource cost has diverse ratio with it.

One resource owner just at overload conditions doesn't accept one job. Therefore, we used from all resource in the ratio of their speed and it is fair method.

Experiment and Observations

Job and Resource Characteristics

We used experimental data evaluate the effectiveness our proposed approach. There are six clusters in our experiment. We named them R0 to R6, and for the characteristic see Table 1.

We assume one processor on each resource. In experiment changes the number of jobs from 500 jobs to 2,500 jobs. Every job arrives, is allocated one or more processors for a period of time, and then leaves the system. Furthermore, every job in the workload has an associated arrival time, indicating when it was submitted to the scheduler for consideration.

The simulator was implemented using the GridSim toolkit that allows modeling and simulation of distributed system entities for evaluation of scheduling algorithms.

To enable parallel workload simulation, we extended the existing GridSim's AllocPolicy, Gridlet and SpaceShared. Our simulation environment models the GFA, GFAResource and GatherResult entities in addition to existing entities in GridSim.

Table 1 Resources configuration

	R1	R2	R3	R4	R5	R6
MIPS rating	850	900	700	630	930	710
Price	6.84	5.12	5.98	4.59	5.3	4.04

For evaluating the pricing method, we compared it to pervious work, that price only was depended to the resource owner supply and we named it, static price.

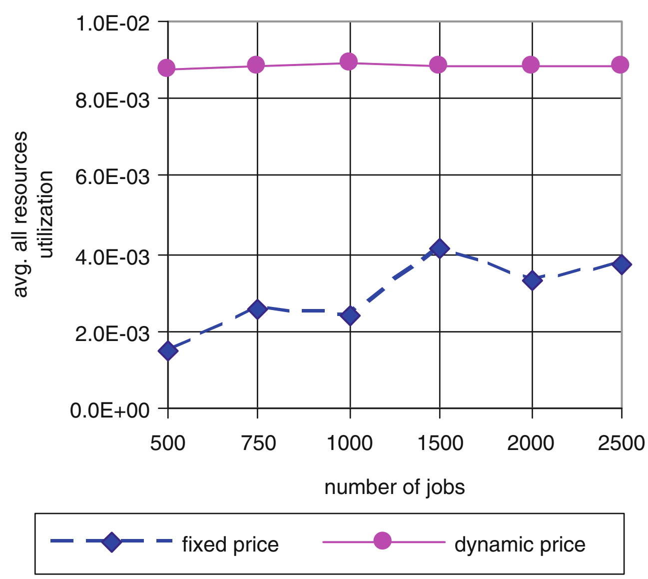
We quantify the following scheduling parameters related to resource owners and end-users:

Resource owners: payoff function (total earning), resource utilization (in terms of total MI executed);

End-users: QoS satisfaction: average budget spent, number of jobs accepted and total duration time.

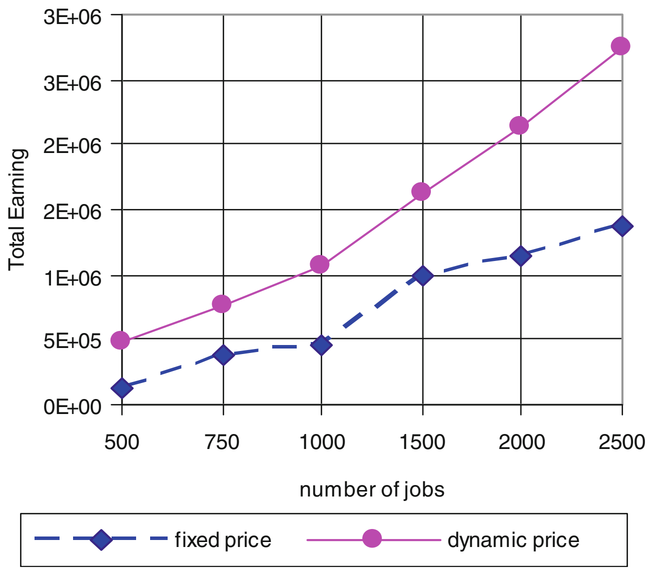
In these experiment, we fixed the negotiation delay of SLA bid is fixed and it is 30 % of total allowed job deadline.

Experiment 1: Quantifying Total Resources Utilization with Varying Number of Jobs



In this experiment, we compare resource utilization at two state, fixed prices and dynamic price. As we observed, total resources utilization increase, when the resource's price changes within user's agreements. This is because of, at the fixed price state, some expensive resource will become useless and they have very low or even no utilization.

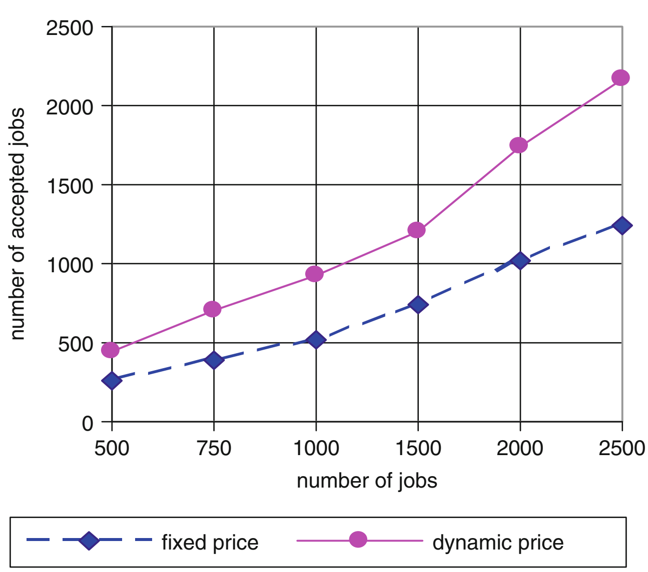
Experiment 2: Quantifying Total Resources Earning with Varying Number of Jobs



As we observed, also total resources earning have been increasing in our proposed method in the ratio of fixed price, because of more demands are accepted and done by resource owners by changing their price, therefore, their total earning is increased, too.

Hence, we can see that proposed approach leads to better optimization of resource owners' payoff function, because it decreased total free times of resources, very much, and grows up their total earning.

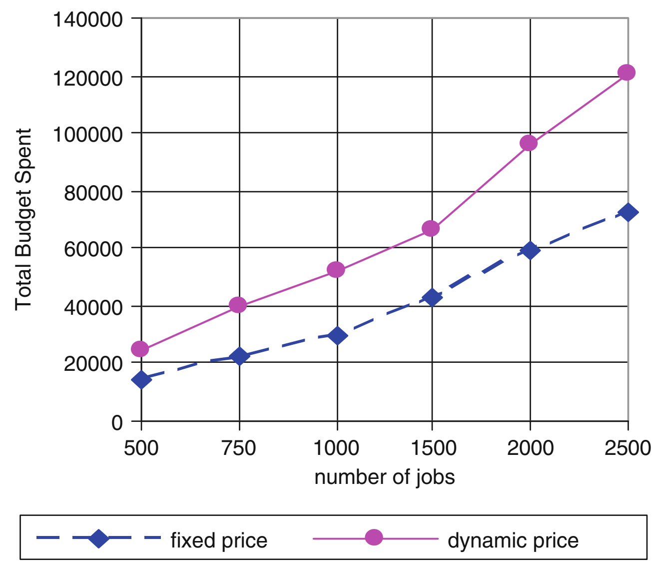
Experiment 3: Quantifying Number of Jobs Accepted with Varying Number of Jobs



We observed that, the number of accepted jobs in our method is much than fixed price method. Because of in the previous method, convenient resources with appropriate price have very demand and at result very high work load, expensive resources have low load, but many of users can't pay the cost of those resources and at final drop from system, however, properly there are some free resource within jobs' desired intervals.

Hence, our approach leads to improving of end-user's QoS satisfaction. Therefore, this approach not only is better for resources owners, but also, it's better for end-users' accepted jobs.

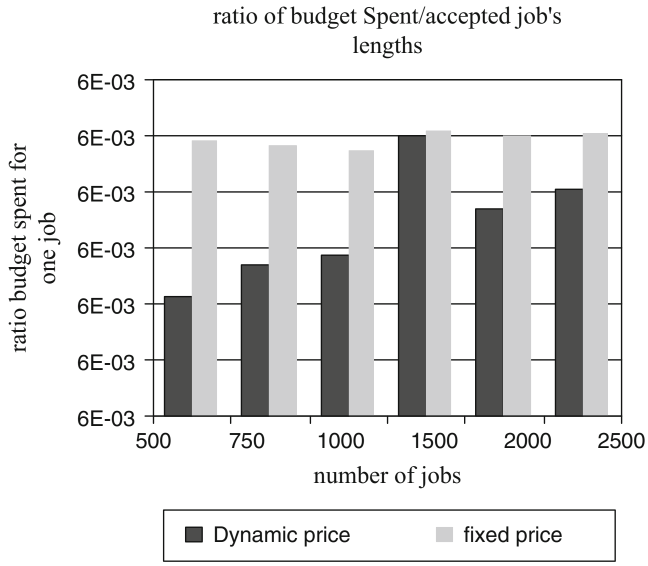
Experiment 4: Quantifying Total Budget Spent with Varying Number of Jobs



As we observed in this diagram, total budget spent in our approach is more than fixed price approach. However, of user's perspective this is usual, because the number of accepted jobs is more and it is natural that user spent more budget for doing all of them.

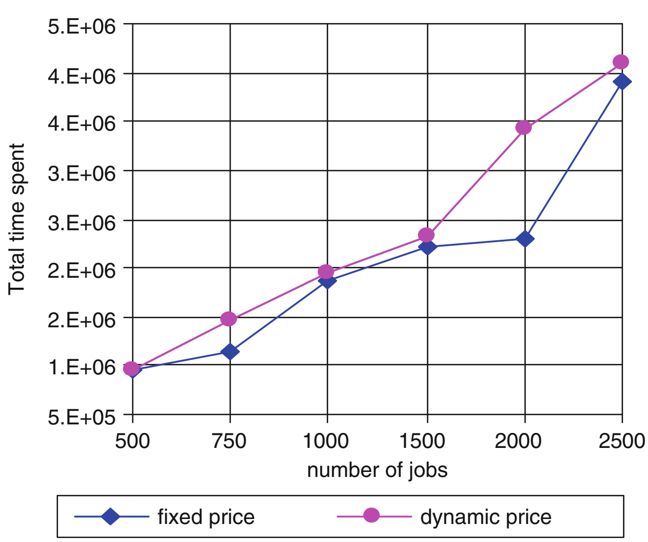
But one noted is important here and it is, for example, from 2,000 jobs, in our approach 1,985 jobs are accepted and at fixed price 1,026 jobs accept, if at fixed price 1,985 jobs have been accepted, too. Whatever total budget spent be more from now or less?

For experiment this issue, we calculate the budget spent for one job in both approach. In the following diagram, we calculate ratio of total budget spent on the length of jobs accepted, and obtained average budget spent for one jobs.



As we observed, in all case jobs, the rate of budget spent in fixed price is more than dynamic price, and it proves our predictions.

Experiment 5: Quantifying Total Duration with Varying Number of Jobs



We observed that in this approach, total time spent is more than fixed price approach. We resulted, when more jobs accepted and done in system, it cause increasing in total spent time.

Conclusion and Future Works

In this paper, we presented an improving over SLA-based super scheduling and greedy backfilling for scheduling resources. Our improvement is a pricing algorithm for allocation resources. In addition, our pricing algorithm is useful generally for P2P grid computing and in comparison with commodity market models is simple to use. In our proposed approach, if customer and provider agree about other job's conditions, by applying our method and considering resource work load price balancing almost is made. In changing price we also attention to job's budget, because we want users be satisfied in system, too. By using this algorithm system will reach estimating load balancing state. According done simulation and their result, improvement this approach in the ratio of previous approach presented.

In the future work, we can investigate the effect of other common economics models on the used background. Just peer-to-peer models are convenient for this environment. Because the communication is peer-to-peer, and can't use auction base model or one to many or many to many models. We also intend to look into simultaneously bidding for SLA contracts at multiple contractors in the net, for super scheduling iteration.

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A Comparative Analysis of Bayesian Nonparametric Inference Algorithms for Acoustic Modeling in Speech Recognition

John Steinberg, Amir Harati, and Joseph Picone

Abstract

Nonparametric Bayesian models have become increasingly popular in speech recognition for their ability to discover data's underlying structure in an iterative manner. Dirichlet process mixtures (DPMs) are a widely used nonparametric method that do not require a priori assumptions about the structure of the data. DPMs, however, require an infinite number of parameters so inference algorithms are needed to make posterior calculations tractable. The focus of this work is an evaluation of three variational inference algorithms for acoustic modeling: Accelerated Variational Dirichlet Process Mixtures (AVDPM), Collapsed Variational Stick Breaking (CVSB), and Collapsed Dirichlet Priors (CDP).

A phoneme classification task is chosen to more clearly assess the viability of these algorithms for acoustic modeling. Evaluations were conducted on the CALLHOME English and Mandarin corpora, consisting of two languages that, from a human perspective, are phonologically very different. In this work, we show that these inference algorithms yield error rates comparable to a baseline Gaussian mixture model (GMM) but with a factor of 20 fewer mixture components. AVDPM is the most attractive choice because it delivers the most compact models and is computationally efficient, enabling its application to big data problems.

Keywords

Bayesian nonparametric • Analysis • Speech recognition • Algorithms

Introduction

Nonparametric Bayesian models have become increasingly popular in speech recognition due to their ability to discover data's underlying structure in an iterative manner [1]. Dirichlet process mixtures (DPMs) are a widely used nonparametric method that do not require a priori assumptions about the structure of data, such as the number of mixture components, and can learn this information directly from the data [1]. This is ideal for acoustic modeling in speech recognition where the number of mixtures is a parameter commonly found by tuning a system using a subset of the data. Typically, the number of mixtures is assumed to be constant since it would be tedious to tune this parameter for each model (the number of models can often exceeds 10,000 in a state of the art system). DPMs are able to automatically determine an optimal number of mixtures for each individual model.

There are many depictions of Dirichlet processes but the algorithms in this work are all premised on the stick breaking approach shown in Fig. 1. In this representation a stick of unit length is broken repeatedly into smaller pieces. Each break represents a new mixture component weight where the fraction of the remaining stick is given by v_i and the absolute length of each piece (i.e. the weight of the mixture component) is given by c_i.

Aside from automatic tuning of the number of mixture components, it is equally important to ensure that these models generalize well across different data. Our long-term interest

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_61,

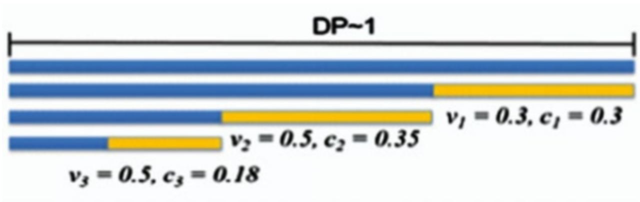

Fig. 1 A diagram of the stick breaking representation of a Dirichlet process is shown. The absolute *length of each stick* corresponds to a mixture component weight. These weights are constrained to sum to 1

in nonparametric Bayesian approaches, and advanced statistical models in general, is to develop models that are robust to significant variations in the acoustic channel. Low complexity models that have good generalization are a step in this direction. In this work, the performance of three Bayesian variational inference algorithms—Accelerated Variational Dirichlet Process Mixtures (AVDPM), Collapsed Variational Stick Breaking (CVSB), and Collapsed Dirichlet Priors (CDP) [2]—are assessed on both the CALLHOME English (CH-E) and the CALLHOME Mandarin (CH-M) corpora.

Variational Inference Algorithms

Nonparametric methods such as DPMs, although extremely useful for finding the underlying structure of data, often come at a cost of computational complexity. The term 'nonparametric' is something of a misnomer since DPMs require a potentially infinite number of parameters. This makes manipulating such distributions intractable, so inference algorithms are used to approximate these models. Markov chain Monte Carlo (MCMC) methods, such as Gibbs sampling, are extremely popular for their simplicity [4–6]. These methods approximate complex posteriors by sampling latent variables from a Markov chain that represents the distribution of interest [7]. Unfortunately, converging to optimal posterior approximations is often slow and these methods can become intractable for big data problems such as speech recognition [5, 7].

Variational inference algorithms approximate a posterior, $p(y|x)$, with a simpler distribution $q(y)$ by making assumptions about the dependencies of the distribution's latent variables. The task of approximating a complex distribution is transformed into an optimization problem where an optimal q is found from a set of variational distributions $Q = \{q_1, q_2, \ldots, q_m\}$ such that an objective function, i.e. Kullback–Leibler divergence, is minimized. The introduction of these efficient inference algorithms [2] recently has made applications such as speech recognition computationally feasible.

English and Mandarin Speech Recognition

As of 2009 Ethnologue reported 6,909 living languages in the world. Mandarin and English are ranked one and three (respectively) of the most commonly spoken [8]. Moreover, these two languages come from separate families and are linguistically and phonetically very different. For these reasons English and Mandarin are selected to ensure that the performance of AVDPM, CVSB, and CDP are not heavily influenced by any language specific artifacts.

Based on NIST benchmarks Mandarin speech recognition tasks have historically yielded worse error rates than comparable English ones [9]. There are many factors that this disparity can be attributed to such as Mandarin's flexible grammatical structure, relatively high number of homophones (about 1,300 syllables compared to approximately 10,000 for English [10]) and, most conspicuously, the tonal nature of the language. Unlike English, whose phoneme labels are all unique, each vowel in Mandarin can take five different tones (4 distinct tones and 1 neutral tone). Thus, where English has approximately 40 phoneme labels, Mandarin actually has close to 90. The scope of this work is constrained to phoneme recognition so that other factors, such as language modeling, are decoupled.

Nonparametric Bayesian Approaches

Parameterized models have been widely applied to clustering and classification problems for their ease of use, simplicity, and reasonable performance. Unfortunately, they require making assumptions about data structure and sometimes generalize poorly. Nonparametric methods, on the other hand, do not suffer from these limitations but, due to their complex nature, require inference algorithms to make posterior calculations tractable. In this section, a brief overview of one such nonparametric method, a Dirichlet process mixture (DPM), is provided.

Dirichlet Distributions and Dirichlet Processes

One of the main drawbacks of typical, parametric speech recognition systems is the assumption that the number of mixture components for each phoneme model is known and is held constant for every model. For complex data such as speech this is largely presumptuous and it would be more reasonable to assume that each phoneme model has its own unique structure.

Creating a model to characterize the optimal number of mixture components is best represented by a multinomial

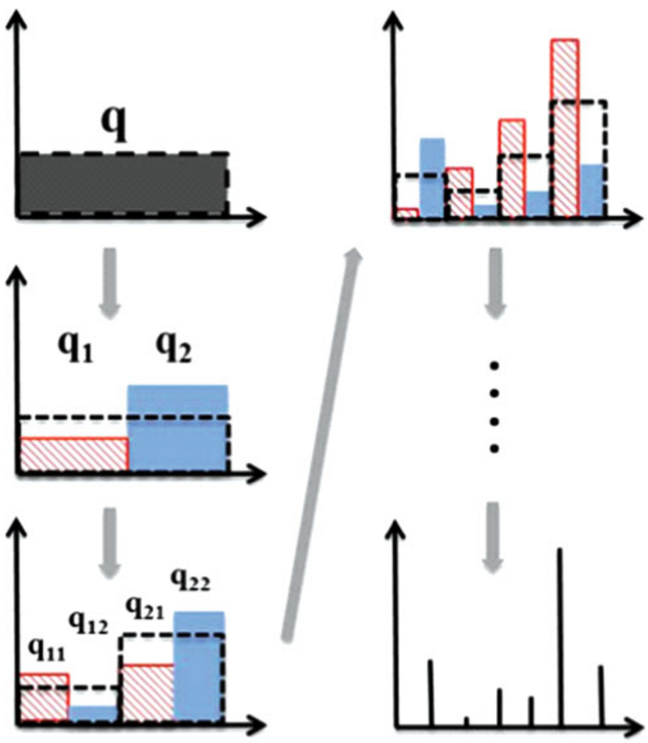

Fig. 2 A diagram showing how splitting a Dirichlet distribution infinitely many times yields discrete values

distribution. To model this in a statistically meaningful way priors are needed to ascertain information such as the number of mixture components and their respective weights. Dirichlet distributions act as the conjugate prior for the multinomial distribution, and in the case of this work, can be used to find the optimal number of mixture components. An extension of the Dirichlet distribution, the Dirichlet process (DP), is used to then generate discrete priors for modeling the respective weights of these components.

A Dirichlet distribution (DD) is often referred to as a distribution over distributions and is given by:

$$Dir(\alpha) \sim f(q;\alpha) = \frac{\Gamma(\alpha_0)}{\prod_{i=1}^{k}\Gamma(\alpha_i)} \prod_{i=1}^{k} q_i^{\alpha_i - 1} \tag{1}$$

where q and α are a set of distributions and their respective concentration parameters (i.e. inverse variances) such that $q = |q_1, q_2, \ldots, q_k|$, $q_i \geq 0$, $\sum_{i=1}^{k} q_i = 1$, $\alpha = |\alpha_1, \alpha_2, \ldots, \alpha_k|$, $\alpha_i > 0$, and $\alpha_0 = \sum_{i=1}^{k} \alpha_i$. Furthermore, the decimative property of DDs explains that each distribution, q_i, can be split in such a way that $(q_{11}, q_{12}, q_2, \ldots, q_k) \sim Dir\ (\alpha_1\beta_1, \alpha_1\beta_2, \alpha_2, \ldots, \alpha_k)$ where $q_{11} + q_{12} = q_1$ and $\beta_1 + \beta_2 = 1$.

A DP is a DD split infinitely many times, ultimately generating discrete values that serve as priors. This can be seen in Fig. 2 where a DD is initially set to a uniform distribution. After an infinite number of splits, the resulting distributions are infinitely narrow and essentially discrete values are obtained which serve as priors for the models in this work. Although there are many representations of DPs, all three algorithms used in this work focus on the stick breaking approach shown in Fig. 1.

Variational Inference Algorithms

Variational inference converts the sampling problem of MCMC methods into an optimization problem. A variational distribution, $q(y)$, which has made independence assumptions about model parameters, is used to approximate the posterior, $p(y|x)$. More specifically, these algorithms assume that the distributions that represent stick lengths (and by extension, mixture component weights), component structure (i.e. means and covariances of a Gaussian for this work), and mixture assignments are all independent. This relationship can be seen in (2), (3), and (4) below. By using optimization techniques such as the EM algorithm and the Kullback–Leibler (KL) divergence as a cost function, an optimal $q(y)$ can be found from a set of distributions $Q = \{q_1, q_2, \ldots, q_k\}$. Thus, new stick breaks, i.e. mixture components, are released as the KL divergence is minimized.

Variational inference algorithms can be computationally inefficient and often require additional constraints to make their use viable. AVDPM incorporates KD-trees which can be used during preprocessing to organize the data by partitioning them across hyperplanes in the feature vector space. Lower initial depths essentially result in shorter training times at the expense of accuracy. Moreover, AVDPM limits the number of mixture components to a truncation level, T, such that additional components, $L > T$, can exist but are tied to their priors. For AVDPM the factorized variational distribution is given by [2]:

$$q(z,\eta,v) = \prod_{i=1}^{L}\left[q_{\phi_v}(v_i)\, q_{\phi_\eta}(\eta_i)\right]\prod_{n=1}^{N} q_{z_n}(z_n) \tag{2}$$

where $q_\phi(v_i)$, $q_\phi(\eta_i)$, and $q_z(z_n)$ represent parametric models for stick lengths, the components' structures (e.g. μ and σ for Gaussians), and mixture component assignments respectively. Each of the parametric models' respective parameters are given by ϕ.

CVSB and CDP, on the other hand, do not incorporate KD-trees but instead use a "hard" truncation level. This essentially limits the DPM to a finite but large number of mixture components, T. The variational distribution for CVSB is almost identical to that used for AVDPM [2]:

$$q(z,\ \eta,\ v) = \left[\prod_{n}^{N} q(z_n)\right]\left[\prod_{t=1}^{T} q(\eta_t)q(v_t)\right]. \tag{3}$$

While CVSB can have variable stick lengths, CDP imposes a symmetric prior on the variational distributions, i.e. the lengths of k stick breaks are all equal and thus weights of mixture components are all equal. This essentially reduces the DP to a DD and allows for the exchangeability of labels. The factorized variational distribution for CDP is [2]:

$$q(z,\ \eta,\ c) = \left[\prod_{n}^{N} q(z_n)\right]\left[\prod_{k=1}^{T} q(\eta_k)\right] q(c)\ . \tag{4}$$

The primary difference between (3) and (4) is the replacement of $q(v)$ by $q(c)$. The ith stick break, v_i, represents the fraction of the remaining stick length and is modeled with a beta distribution [7] while c_i is the actual mixture weight (i.e. the fraction of the original, whole stick). Since the length of each stick break is held constant, the effect from the stick lengths can be removed from the product in (3) and replaced by $q(c)$.

Experimental Setup

In this work, the performance of AVDPM, CVSB, and CDP was compared to a standard Gaussian mixture model. Labels for the CH-E Corpus consisted of the 39 phonemes found in the CMU7 dictionary [14] as well as three additional labels—sp, sil, and a garbage phoneme—which were added to account for any partial words or sounds in the data. The CH-M Corpus contains 92 phoneme labels consisting of the labels found in the CH-M lexicon and the 3 additional labels used in CH-E Corpus. Furthermore, English words that exist in CH-M are added to the CH-M lexicon where any English vowel sounds are assigned to the neutral tone. The relatively high number of labels is due to the tonal nature of Mandarin, which requires all vowel sounds to have five labels (e.g. vowel “a” is actually “a1”, “a2”, “a3”, “a4”, and “a5”).

Phoneme alignments were generated by training a hidden Markov model (HMM) based acoustic model using a flat start and training up to 16 monophone mixtures. Finally, a Viterbi alignment was performed to identify phoneme segments. Any utterances from the corpora that contained simultaneous speech from multiple speakers were discarded.

Using the generated segmentations, 13 MFCC features and their first and second derivatives were extracted using a frame duration and window duration of 10 ms and 25 ms respectively. The frame-based features from each phoneme segment were averaged in a 3-4-3 manner so that the number of features per segment was constant despite duration (although duration was added as a single additional feature). Models were trained for each phoneme label and predictions were generated using maximum likelihood. Diagonal covariances were used to train the GMM models and the number of mixture components was held constant for all phoneme labels. Conversely, AVDPM, CVSB, and CDP found this number, and the corresponding means and covariances, automatically.

The best of 10 iterations of the GMM baseline was compared to the average performance of AVDPM, CVSB, and CDP over 10 iterations. Performance was evaluated using both error rates and the average number of mixture components per phoneme label.

These algorithms were initially evaluated on the well-calibrated TIMIT Corpus to confirm that this setup produced comparable performance to other published results. Following the methods in [11–13], the corpus was partitioned into training, validation, and evaluation sets. The 61 original phonemes that exist in TIMIT were collapsed to 39 labels. GMMs were first fit using the phoneme alignments provided with TIMIT. The number of mixture components was varied for the GMMs and an optimal performance of 31.56 % misclassification error was achieved for four mixture components per phoneme label. This was comparable to the results found in [13] although for a much lower number of mixture components (i.e. 4 mixtures vs. 64 mixtures). This discrepancy was due to the use of features only from the central portion of each phoneme segment instead of the 3-4-3 approach used in this work [13]. With this confirmation, phoneme alignments were then generated for the collapsed 39 labels in the same manner used for CH-E and CH-M. These results are discussed in the following section and allowed for a better comparison to the performance on CH-E and CH-M.

Results and Discussion

The truncation level for CVSB and CDP was varied to determine an optimal operating point for each corpus. Similarly, the initial depth of the KD tree was adjusted for AVDPM to determine the effect on performance. Each algorithm was iterated ten times and an average misclassification error rate was calculated. The best error rates are shown in Table 1, along with their associated parameter values.

It can be seen that the average misclassification error of all three variational inference algorithms yield comparable error rates and require significantly fewer mixture components than the baseline GMM model where the number of components is assumed to be known a priori. This is due to the ability of DPMs to discover the underlying structure of the data and consequently less prone to overfitting.

It is interesting to note that relative performance of CVSB and CDP was worse for TIMIT than both CH-E and CH-M. This is most likely an artifact of the studio recorded, read speech of TIMIT which allows for the fixed number of

Table 1 A comparison of the best misclassification error and number of mixture components for the evaluation sets of the TIMIT, CH-E, and CH-M corpora

	TIMIT		CH-E		CH-M	
Model	Error (%)	Notes	Error (%)	Notes	Error (%)	Notes
GMM	38.0	# Mixt. = 8	58.4	# Mixt. = 128	62.7	# Mixt. = 64
AVDPM	37.1	Init. Depth = 4	57.8	Init. Depth = 6 Avg. # Mixt. = 5.14	63.5	Init. Depth = 8 Avg. # Mixt. = 5.01
CVSB	40.3	Truncation Level = 4	58.7	Truncation Level = 6 Avg. # Mixt. = 5.89	61.2	Truncation Level = 6 Avg. # Mixt. = 5.75
CDP	40.2	Truncation Level = 4	57.7	Truncation Level = 10 Avg. # Mixt. = 9.67	60.9	Truncation Level = 6 Avg. # Mixt. = 5.75

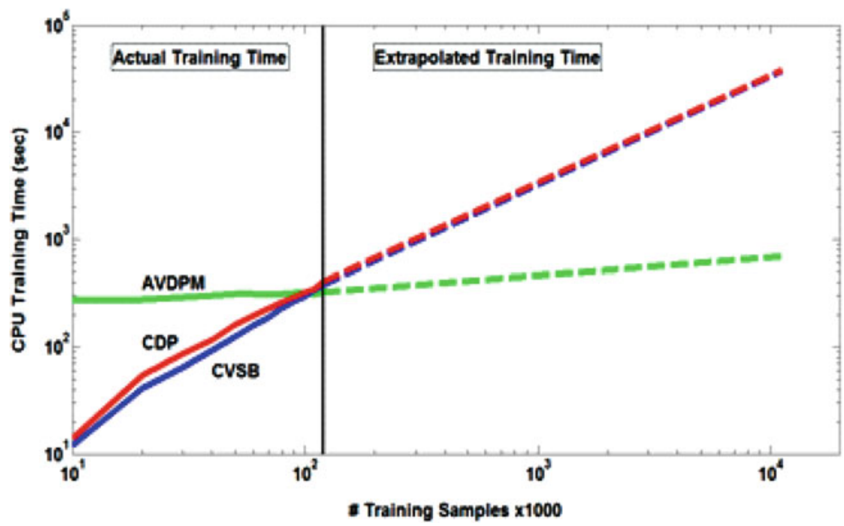

Fig. 3 A diagram showing how the CPU training time changes as the amount of training data increases

mixture components of the GMM to reasonably approximate the underlying structure of the data. Conversely, CVSB and CDP are better suited to conversational telephone speech where the underlying structure is less apparent. Finally, the relatively small disparity between Mandarin and English can easily be attributed to Mandarin having more than double the number of phoneme labels as English, i.e. each phoneme's model is trained on less than half the number of segments as those for English.

It can be seen in Table 1 that both CH-E and CH-M have the same optimal truncation levels for CVSB and CDP with the exception of CDP on CH-E. This is not unexpected since the symmetric prior CDP imposes on the lengths of the stick breaks indicates that there should be an equal or greater number of mixture components compared to those found by CVSB to compensate for that assumption.

AVDPM's performance and average number of mixture components are comparable to both CVSB and CDP. However, the incorporation of KD trees make it more attractive for acoustic modeling since larger data sets can be managed by trading off the depth of the KD tree. The computational complexity of this algorithm grows rapidly as depth increases [2], but it can be seen in Table 1 that speech from significantly different recording environments have optimal operating points at similar initial depths of the KD tree. Although the optimal depth for CH-E and CH-M are 6 and 8, reducing the depths to 4 was found to only marginally worsen the error rates (by 1.32 and 1.14 % respectively).

This is particularly interesting as Fig. 3 shows the actual measured CPU times for training as a function of the amount of training data for AVDPM, CVSB, and CDP. CPU times were obtained using optimal operating points on TIMIT when the initial depth of the KD tree is set to 4 for AVDPM and the truncation level to 4 for both CDP and CVSB. These plots were extrapolated to show the theoretical training time for a much larger corpus such as Fisher [15]. We have generated these extrapolated results using simulated data since we do not have access to corpora of this size. These run-time differences held for simulated data and should not be data dependent.

It can be seen here that the required training times of CVSB and CDP grow rapidly as the number of training samples increases. Furthermore, CH-E and CH-M require higher truncation levels. As can be seen in Table 1, these algorithms generally choose the maximum number of mixture components (this is at least true for relatively low truncation levels). This indicates that the training time should increase linearly as the truncation level increases. The error rates generated by AVDPM are optimal (or very near optimal) at a low initial depth of the KD tree. The complexity of initially building the KD tree has a significant cost which accounts for the relatively large gap in training times for small amounts of training data between AVDPM and CVSB or CDP. However, it is shown in Fig. 3 that the training time required by AVDPM is significantly less affected as the amount of data increases and would be almost two orders of magnitude faster when training on a large corpus such as Fisher.

Conclusions

Dirichlet distributions, and by extension DPMs, can be used to find underlying structure of data, e.g. the number of mixture components in a GMM. For further improvements these nonparametric models can be extended to HMMs to not only find the structure of each state's distribution but to also find the structure of the HMM itself, i.e. the number of states and the transitions between them. However, due to these methods' infinite parameters inference algorithms are needed to make posterior calculations tractable. In this work, it is shown that three variational methods—AVDPM, CVSB, and CDP—are not subject to language specific artifacts and yield comparable performance to baseline GMMs but with significantly fewer parameters.

CVSB and CDP have optimal truncation levels between 4 and 10 for speech data and can perform well on small corpora such as TIMIT. However, AVDPM is best suited to acoustic modeling since controlling KD tree depth allows for the tradeoff between accuracy with available computational resources, thereby making training on large corpora possible. An initial depth of 4 for AVDPM yielded optimal, or very near optimal, results for data ranging from cleanly recorded read speech to noisy conversational telephone speech. Furthermore, this algorithm is significantly less affected by the amount of training data and is theoretically able to train large corpora orders of magnitude faster than CVSB or CDP.

Acknowledgements This research was supported in part by the National Science Foundation through Major Research Instrumentation Grant No. CNS-09-58854. Our research group would also like to thank the Linguistic Data Consortium (LDC) for awarding a data scholarship to this project and providing the lexicon and transcripts for CALLHOME Mandarin.

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Requirements Based Estimation Approach for System Engineering Projects

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Abstract

In this paper the requirements are used for the purpose of the estimation. Requirements are cluster according to their complexity. The new approach in the papers is based on requirements analysis. The complexity of the requirements is set and Total Requirements Points Value (TRP) is calculated. The Total Requirements Points are modified by the technical and environmental factors, which described the problem domain and the development team experiences. The Total Requirements point can be used as a coefficient for the system size. According this approach system-engineering project can be compared and priced.

Keywords

Effort estimation • System engineering • Use case points

Introduction

The system engineering as a discipline covers a broad number of subject at present time. Military application [1], robotics [2], [5] or similar systems can be recognized as system in the scope of system engineering.

The system engineering has generic process. The process consists of five basic steps. These steps are requirements analysis, design, development, testing and validation. Requirements engineering is the first step and therefore takes key role in the whole system development.

The methodology of the system estimation method for a system-engineering project is presented. The method is based on the clustered requirements approach [5], and by use case points method [3].

The use case points method [3], is an approach, based on the Use Case Model, which is uncommon in the System Modeling Language. The model is used for the system function description. The Use Case model is composed of the actors, which are external entity and of the use cases. The use cases represent system functions or algorithms. Each of the use case has to realize one of the requirements as minimum.

The Use Case is description of the activity of the action in the system. The use case model in the system engineering consists of the actors, use case and associations.

A use case is written in form of the scenario. The scenario represents sequence of the steps, which represents using of the system by an actor.

The actors and scenarios are the base factor in the estimation methodology, called use case points.

Scenarios provide a brief description of an activity of an actor in a system. Other common definition describes a scenario as internal part of a business process, which is solved by a system itself [4].

For purpose of estimation, number of steps in the scenario is significant [3]. The number of steps represents the scenario or use case complexity; therefore, a system complexity is represents by the number of use cases.

For analyzing the system, complexity is necessary to analyze the use cases, which were created based on requirements. The quality of use cases is important for the correct estimation without occurring errors.

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_62,

The organization of this contribution is as follows. Second section describes the problem formulation. Third section describes the proposed method of the estimation. Fourth and fifth sections describe technical and environmental factors. Sixth section describes calculation formulas. Seventh section describes a case study of the proposed methodology. Finally eighth section is a conclusion.

Problem Formulation

The majority of well-known methods are based on similarity or on the use case model analysis. Creating the use case model is a complex task. Niche of the research is to preparation of the method, which will lead to estimation at very beginning of the development process.

The initial step of each development is called requirements analysis. As a result of the step the requirements definition document is created. In such document the system requirements can be found.

The system size, development time and development costs estimation is non-trivial task. This estimation is necessary for price negotiations. The system developers should have more précises method for pricing than Delphi method or experienced based methodologies.

Therefore, in the following text, we are describing our algorithmic method, called system size estimation method.

Estimation Approach Definition

For the purpose of the estimation, the analysis of the requirements is necessary. The process of the estimation consists of following steps:

1. Set the importance of the requirement.
2. Set the complexity level of requirement.
3. Calculation of the Technical Factor.
4. Calculation of the Environment Factor.

The requirements are clustered into three groups. Complexity of the each group can be:

$$\text{complexity} = \{\text{simple}; \text{avarage}; \text{complex}\} \tag{1}$$

The simple set contains requirements, which have software-based implementation and are solved by 1 individual subsystem. Calculation weight value is 5, as can be seen in the Table 1.

The average set contains requirements, which have hardware user interface or data processing. Calculation weight value is 10.

The complex set contains requirements, which involves a technology control, mechanical user interface or very complex data processing. Implementation involves more than 1 subsystem. Calculation value is 15.

Table 1 Complexity list

Complexity	Calculation weight (C_f)
Simple Non-functional RQ (NF)	5
Average System characteristics (SC)	10
Complex Constrain RQ (CR)	15

The total value of parameters is calculated for each group:

$$\text{Simple}: \sum (\text{NF} \times \text{Cf}) \tag{2}$$

$$\text{Average}: \sum (\text{SC} \times \text{Cf}) \tag{3}$$

$$\text{Complex}: \sum (\text{CR} \times \text{Cf}) \tag{4}$$

These values, when summed determines the Raw Requirements Poins (RRP). According the following formula:

$$\text{RRP} = \sum (\text{NF} \times \text{Cf}) + \sum (\text{SC} \times \text{Cf}) + \sum (\text{CR} \times \text{Cf}) \tag{5}$$

Technical Factors

There are a 15 technical factor. These factors can be seen in the Table 2. The factor are revised version of the early published work [4].

The role of the impact is to provide a description of problem domain form technical point of view.

Each factor is weighted according to its relative impact. A weight of zero indicates the factor is irrelevant and the value 5 means that the factor has the most impact.

Technical factors are used for Total Technical Factor value (TTV). Each TF values is multiple by value of its significance (TFs):

$$\text{TFs} = \langle 0.10 \rangle, \text{ for each TF} \tag{6}$$

Technical Factors Value (TFV) is calculated as follows:

$$\text{TFV} = \sum (\text{TFs} \times \text{Ve}) \tag{7}$$

As can be seen TFV represents weighed value of each TF (T1–T15).

Table 2 Technical factors

TF	Description	Value (V_e)
T1	Distributed architecture	2
T2	Business critical	5
T3	Performance	1
T4	End user efficiency	1
T5	Complex internal processing	1
T6	Reusability	1
T7	Usability	0.5
T8	Safety	5
T9	Security	1
T10	Sociotechnical aspect	2
T11	Modular architecture	2
T12	Maintenance	2
T13	Upgradability	2
T14	Graphical user interface	5
T15	Long LifeTime	2

Table 3 Environmental factors

EF	Description	Value (V_e)
E1	System designer experience	2
E2	Domain experience	1
E3	Modelling experience	2
E4	Analysis capability	2
E5	Motivation	1
E6	Stable requirements	2
E7	Subcontractors	5
E8	Integration complexity	5
E9	Ecological impact (development)	3
E10	Public importance	1
E11	Cost of the shelf	5
E12	Regular cooperation	−1
E13	National level evaluation	1
E14	Methodology experience	5
E15	Certification	2

Environmental Factors

Environmental Factors (EF) estimates the impact on productivity that various environmental factors have during the system development. Their role is describe development environment and moreover the problem domain itself.

The list of the proposed environmental factors can be seen in Table 3. The factors are evaluated and weighted according to its perceived impact and assigned a value between 0 and 10. A value of 0 means the environmental factor is irrelevant for this project; 5 is average; 10 means it has strong impact.

Environmental factors are used for Total Environmental Factor value (EFV). Each EF value is multiple by value of its significance (EFs):

$$\text{EFs} = \; < 0, 10 > , \text{ for each EF} \tag{8}$$

Environmental Factors Value (EFV) is calculated as follows:

$$\text{EFV} = \sum (\text{EFs} \times \text{Ve}) \tag{9}$$

As can be seen EFV represents summed weighed value of each EF (E1–E15).

Calculation Formulas

Final result of calculation, the Total Requirements Points (TRP) is calculated according following formula:

$$\text{TRP} = \text{RRP} \times ((\text{CR1} \times \text{TFV}/100) + (\text{CR2} \times \text{EFV}/100)) \tag{10}$$

Values CR1 and CR2 are use for tuning of the method. These values are set according the historical project measurement or statistical evaluation.

The TRP value represents the coefficient of the system size.

Project costs (PC) can be determined according following formula:

$$\text{PC} = \text{TRP} \times \text{PP} \tag{11}$$

Where, Pp is price per on TRP. The value of the Pp is individual for each system engineering company.

The development time (DT) can be predicted in the similar way. Only the difference is that TRP is multiply by the coefficient of the man-hour per one TRP (MHP):

$$\text{DT} = \text{TRP} \times \text{MHP} \tag{12}$$

Case Study

The proposed methodology will be described on the sample project, which was adapted from [6].

In this sample is described development of the pocket audio player. The main important project goal was to offer a solution which was successfully in usability and which offers appropriate functionality.

The proposed requirements model can be seen in the Fig. 1. The diagram illustrates hierarchical structure of the requirements. On the top of the tree the Specification package can be seen. Containment association interconnects other parts. The requirements are grouped in the four basic groups:

1. User Friendliness,
2. Durability,

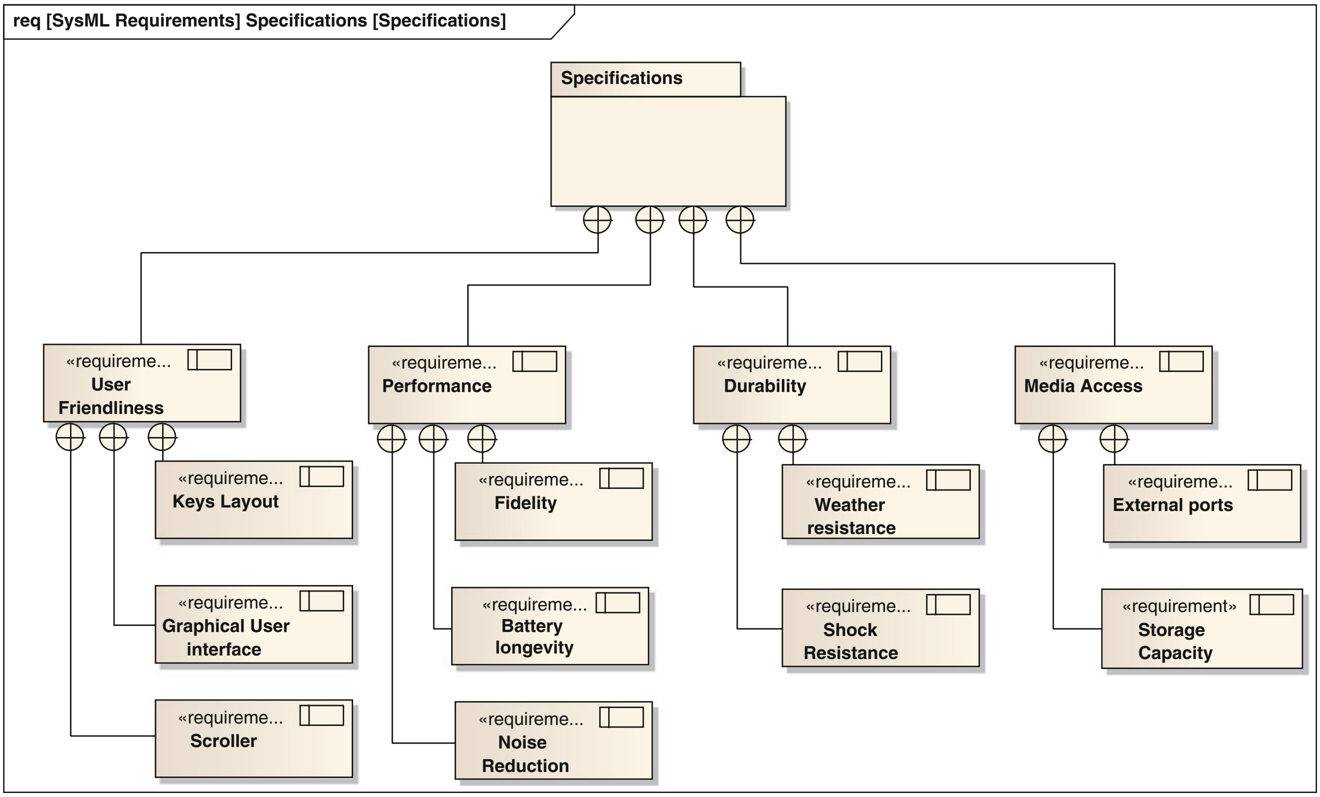

Fig. 1 Sample system engineering project

3. Performance
4. Media Capacity.

The user friendliness group defines set of the requirements, which deal with quality of service of the audio player. Keys Layout, Graphical User Interface and Scroller are primary requirements, which take important role in user satisfaction.

In the project can be found 14 requirements. These requirements can be clustered in the simple, average or complex group:

Simple: 5
Average: 5
Complex 4

Complexity for each groups can be calculated as follows:

Simple: $\sum(5 \times 5)$
Average: $\sum(5 \times 10)$
Complex: $\sum(4 \times 15)$

The Raw Requirements Points are:

RRP $= 25 + 50 + 60$
RRP $= 135$

The next step is to prepare the Technical Factors and Environmental Factors. The Tables 2 and 3 will be used. TFs and EFs values have to be set.

Table 4 Technical factors significance

TF	Description	(Ve)	TFs
T1	Distributed architecture	2	0
T2	Business critical	5	0
T3	Performance	1	10
T4	End user efficiency	1	10
T5	Complex internal processing	1	5
T6	Reusability	1	0
T7	Usability	0.5	10
T8	Safety	5	2
T9	Security	1	0
T10	Sociotechnical aspect	2	5
T11	Modular architecture	2	0
T12	Maintenance	2	0
T13	Upgradability	2	0
T14	Graphical user interface	5	6
T15	Long LifeTime	2	4

In the Table 4 there can be found the significance levels for the each of the Technical factors.

The Technical Factors Value (TFV) is calculated according the formula ($\sum$(TFs $\times$ Ve)). For the case study the TFV $= 88$.

In the Table 5 can be found the Environmental Factors. There can be seen the (EFs) values of the significances of the environmental factors.

The EFV value – according the Table 5 is 66.

Final result of calculation, the Total Requirements Points (TRP) is calculated according following formula 10:

$$\mathrm{TRP} = 135 \times ((0.7 \times 88/100) + (0.5 \times 66/100)).$$

Total Requirements Points are: 83.43

Table 5 Environmental factors significance

TF	Description	(Ve)	EFs
E1	System designer experience	2	0
E2	Domain experience	1	5
E3	Modelling experience	2	5
E4	Analysis capability	2	4
E5	Motivation	1	4
E6	Stable requirements	2	0
E7	Subcontractors	5	0
E8	Integration complexity	5	5
E9	Ecological impact (development)	3	0
E10	Public importance	1	0
E11	Cost of the shelf	5	0
E12	Regular cooperation	−1	10
E13	National level evaluation	1	2
E14	methodology experience	5	4
E15	Certification	2	1

Values CR1 is set to 0.7 and CR2 is set to 0.5. These values are based on average values of the correction values – based on empirical research, which based the historical project measurement evaluation.

Project cost for the sample project is:

PC = 83.49 × 8,500, where PP in (11) is in undefined currency. The result is 709,665.

The development time (DT) can be predicted in the similar way.

DT = 83.49 × 100. This resulted in 8,349 man-hour for the proposed project.

For this calculation can be used an excel table or specific software tool. The proposed tool is CompuEstimator. In the Fig. 2 can be found the sample of the user interface of the application.

Conclusion

In this paper the requirements were used for the system estimation. The estimation method for the system engineering projects were introduced.

The method is inspirited by methods used in the field of software engineering. This methods is based on the Use Case model. For the purpose of the system engineering the estimation is based on the requirements analysis.

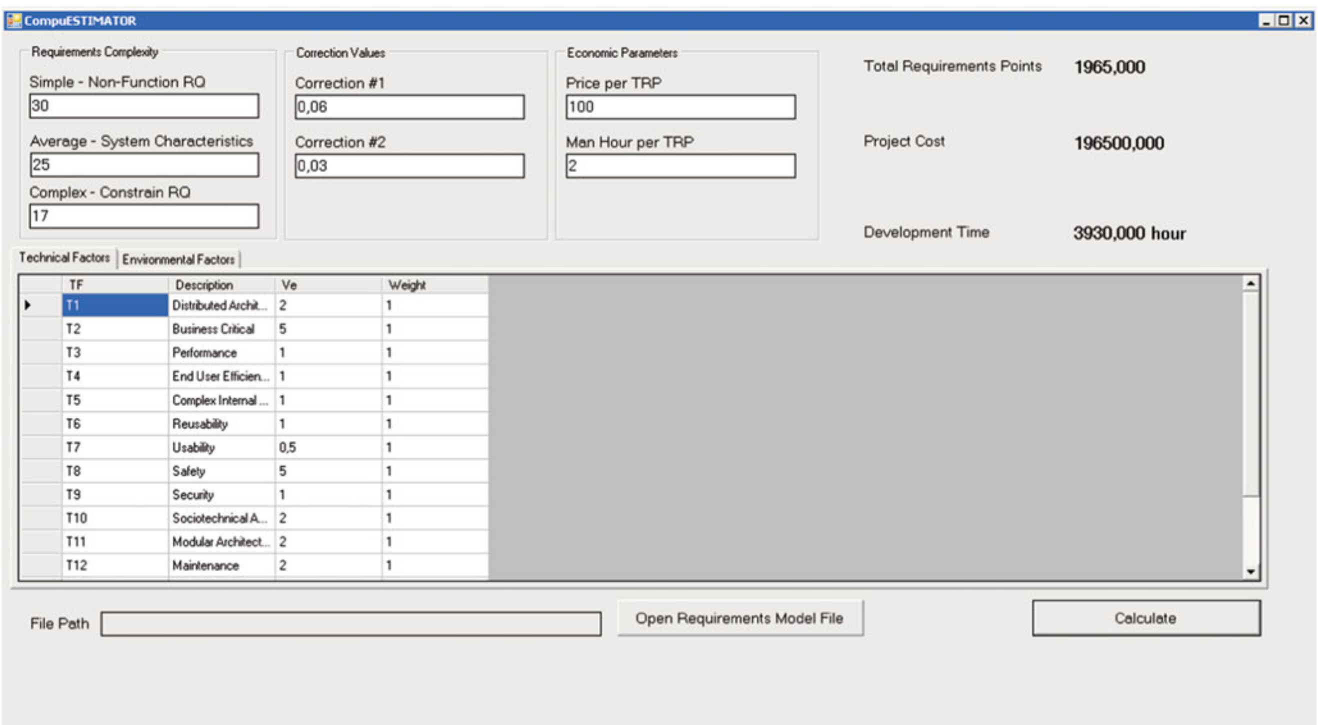

Fig. 2 CompuESTIMATOR software tool

Further research in the project estimation is firstly focused of the appropriate calculation values CR1,2.

Secondly improving accuracy of technical and environmental factors. Thirdly we will investigate method of artificial intelligence for tuning correction factors and weights for technical and environmental factors.

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Improvement of the Time Calculation of Cloud Radiance of One Atmosphere by the Method TDMAP

Bouya Diop, Adoum M. Moussa, and Abdou K. Farota

Abstract

In this work we used the TDMAP model (Tree Driven Mass Accumulation Process) which is the generalization of a suitable wavelet decomposition of fractional Brownian motion (MBF), to improve CPU calculation time of the radiative transfer equation solutions. In the case of radiances, these wavelets are called luxlets. We calculated radiances for a cloudy atmosphere. The calculation is performed on altocumulus with 1.5 g per cubic centimeter of Liquid Water Content (LWC). The results were compared to the same atmosphere with the results of SHDOM (Spherical Harmonic Discrete Ordinate Method). After a statistical study we have good correlation of results from both models and have improved the CPU computation time by 9.3 %.

Keywords

Clouds • Luxlets • SHDOM • TDMAP model

Introduction

The objective of this work is to provide a fast calculation model of the equation of radiative transfer. This new calculation method will allow to the operators of the radiosonde to focus more on satellite remote sensing.

Calculation of cloud luminance from an internal and an external source is urgent problem. But this task, as it is known, requires a lot of memory capacity and computing time.

In this work we used the TDMAP (Tree Driven Mass Accumulation Process) model which is the generalization of wavelet decomposition adapted from a Fractional Brownian Motion in an attempt to improve the CPU (Central Processing Unit) calculation time solutions of the Radiative Transfer Equation (RTE) solutions. In the case of radiances these wavelets are called luxlets. We calculated radiances of a cloudy atmosphere. The calculation is performed on an altocumulus with 1.5 g per cubic centimeter of Liquid Water Content (LWC). These results were compared to the same atmosphere with the results of SHDOM (Spherical Harmonic Discrete Ordinate Method). After a statistical study, we get a good correlation of results two models and we have improved the CPU time calculation by 9.3 % compared to SHDOM. Firstly, we described the two methods then we presented the results.

TDMAP Model

The TDMAP model [1, 2] (Tree Driven Mass Accumulation Process) is a generalization of wavelet decomposition adapted from Brownian motion Fractional [3]. TDMAP the model can be written:

$$X(x) = \sum_{(j,k)\in T_p} 2^{-jH(j,k)} F\left(2^j x - k\right)\zeta_{j,k} \qquad (1)$$

Where X is the process, x the position in the space, Tp is the intermittent p shaft, k is scale, H The Hurst parameter, F the “morphlet” and $\xi_{j,\,k}$ random variables.

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_63,

Considering N (x, Ω), the cloud in the x position and Ω direction.

We can write the following expression:

$$N\left(x,\vec{\Omega}\right) = \sum\nolimits_{j,k} r_{j,k}\phi_{j,k}\left(x,\vec{\Omega}\right) \qquad (2)$$

where $\phi_{j,k}\left(x,\vec{\Omega}\right) = \phi\left(2^j x - k,\vec{\Omega}\right)$ is a luxlet (pre-solution of the radiative transfer equation RTE).

The luxlet $\phi_{j,k}\left(x,\vec{\Omega}\right)$ is the solution of the radiative transfer equation for a spherical cloud of supposed unit radius illuminated from the top.

We tested the existence of a subsequent law that takes into account the scale factor

$\phi(2^{-j\beta}) = 2^{-j\beta}\phi(x)$, β depends strongly on the mean free path of the photon.

For internal sources we use the following expression:

$$S(x) = \sum\nolimits_{\varepsilon jk} s^{\varepsilon}_{jk} T^{\varepsilon}_{jk}(x) \qquad (3)$$

Where $T^{\varepsilon}{}_{jk}(x)$ the temperature at the point of abscissa x

The actinic flux is given by the following expression:

$$q(x,\nu) = \int_{\sum} I(x,\nu,\Omega)d\Omega \qquad (4)$$

Where $I(x, \nu, \Omega)$ is the radiance x, following Ω, for radiation ν.

SHDOM Model

SHDOM (Spherical Harmonic Discrete Ordinate Method) is a FORTRAN algorithm coded to solve with a very good approximation the 3D RTE of the atmosphere [4]. The optical properties (extinction, simple distribution, albedo and phase function) specific grid point are introduced as input data of the SHDOM model.

The possibilities of the model are:

– Calculation of non-biased with a Cartesian grid choice (1D, 2D radiative transfer or 3D) as sources: solar (external collimated) or thermal (internal isotropic)
– Introduction of the extinguishing arbitrary phase function fields.
– Calculation of monochromatic or spectrally integrated flux (with k-distribution method of molecular absorption lines).

Working Hypotheses

We are working on a support of 1 km^3. We assume that there is no external energy. The effect of the Earth in terms of radiation is negligible for both methods. The sky is equal to zero (or cloudless sun). We assume periodic boundary conditions. The cloud as input for both methods is generated by TDMAP. The flow calculations were made from a type stratocumulus cloud with a constant LWC. The radiation used is in the infrared. The phase function is considered constant and equal to 1/4π. The atmosphere in addition to the standard components contains water as vapor and liquid. The atmosphere is free of aerosols. To illuminate a potentially mobile cloud scene: we define a good family "luxlets" then we analyze in "luxlets" and radiance field. The solution of the illumination of the scene is obtained as a synthesis luxlets.

Results

Wavelength of the Radiation λ = 2 μm

The flow calculation is made to the median plane. The calculation result is recorded in the Table 1. The TDMAP model gives the cloud with a mean density of 1.41×10^{-1} and the variance is 4.92×10^{-4}.

The increase corresponds to the meridian plane SHDOM the atmosphere dimension with 1 km^3 the cloud base and top 0.33–1.33 km.

The increase corresponds to the meridian plane TDMAP the atmosphere dimension with 1 km^3 the cloud base at 0 km and 1 km from the summit.

In Figs. 1 and 2, we have the correlations between the flows calculated by the model TDMAP and SHDOM. We note the good correlation between the calculated flow.

Radiation of Wavelength λ = 5 μm

The flow calculation is made to the median plane. The calculation result is recorded in the Table 2. The TDMAP model gives the cloud with a density with mean 1.38×10^{-1} and the variance is 3.14×10^{-4}. The elevation corresponds to the meridian plane SHDOM of the atmosphere which the dimensions are 1 km^3 with the cloud base at 0.33 km and the top to 1.33 km. The elevation corresponds to the meridian plane TDMAP of the atmosphere which the dimensions are 1 km^3 with the cloud base at 0.0 km and the top at 1.00 km.

Table 1 Mean values of the calculated flow for a wavelength equal to λ = 2 μm

Mean values	TDMAP	SHDOM
Elévations	z = 0.50 km	z = 0.830 km
Actinic flux	3.78×10^{-4} W/m^2	2.02×10^{-4} W/m^2
Actinic flux variances	2.06×10^{-8} (W/m^2)^2	4.50×10^{-8} (W/m^2)^2
CPU time	173.71 s	1,868.00 s

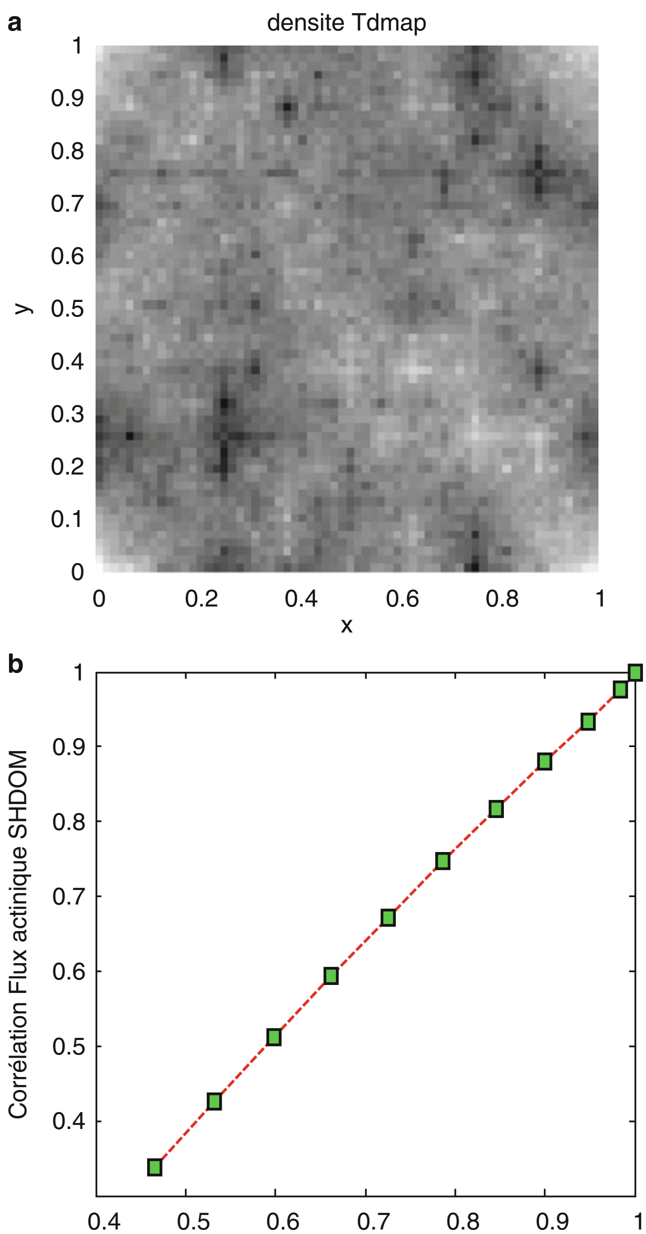

Fig. 1 (**a**) Cloud density given by TDMAP. (**b**) Correlation TDMAP flow, SHDOM flow

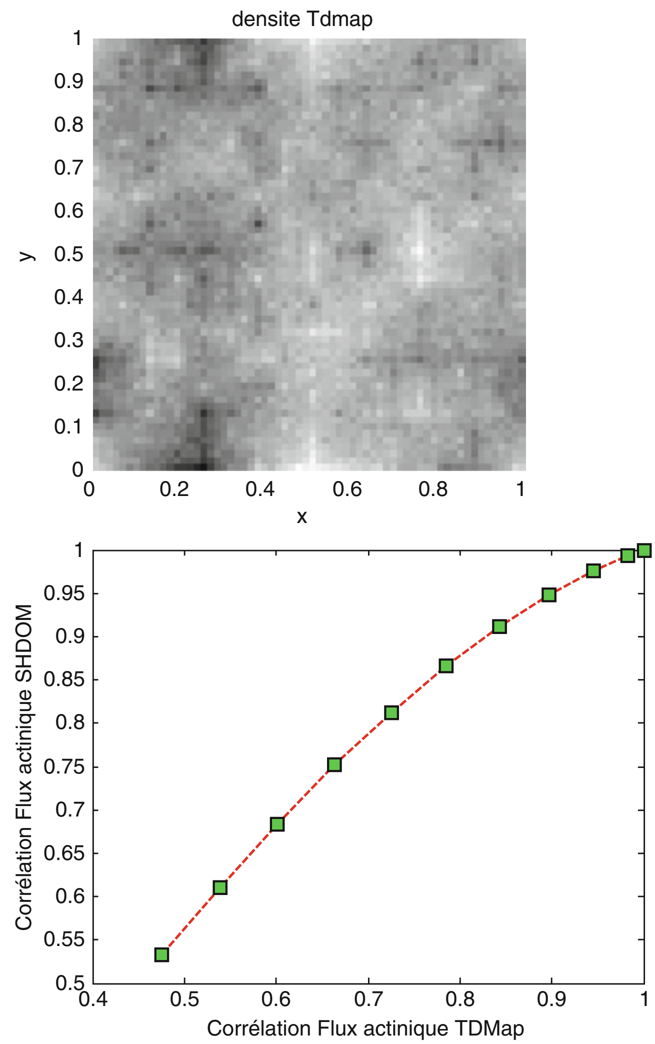

Fig. 2 (**a**) Cloud density given by TDMAP. (**b**) Correlation TDMAP flow, SHDOM flow

Table 2 Mean values of the calculated flow for a wavelength equal to $\lambda = 2\ \mu m$

Mean values	TDMAP	SHDOM
Elevations	z = 0.50 km	z = 0.830 km
Actinic flux	4.35×10^{-4} W/m^2	2.83×10^{-4} W/m^2
Actinic flux variances	1.16×10^{-8} (W/m^2)^2	2.61×10^{-8} (W/m^2)^2
CPU time	166.11 s	1,238.00 s

Conclusion

In this work we have tried to improve the calculation time CPU solutions of the radiative transfer equation. In the case of radiance, these wavelets are called luxlets. We calculated the radiance of a cloudy atmosphere. The calculation is performed on altocumulus with LWC (liquid water content) which is the content of cloud liquid water of about 1.5 g per cubic centimeter. The results were compared with the solution for the same atmosphere with the results of SHDOM.

After a statistical study, we have good relationship and we have improved the time CPU calculation of the order of 9.3 % of radiance.

Acknowledgment We thank the LaMP of the university Clermont II Blaise Pascal (France) for allowing us to achieve these results. We thank Albert Benassi University of Clermont II for allowing us TDMAP use the model, thank Jonas KOKO The Blaise Pascal University for scripts that have allowed us to have these results.

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Process of Transformation, Storage and Data Analysis for Data Mart Enlargement

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Abstract
Creation of the information system is the complex and long process but it is only the first step in its existence. Most of information systems go through a certain development during its life cycle. Very often the users have defined the requests for the enlargement of the functionality and the volume of the displayed data. The process of the transformation, storage and analysis for data mart enlargement based on the users' requests; concretely the data mart of the personal transport is presented in the paper. The expressions from the field of the Business Intelligence and the systems used for gaining data, data analysis or creation of forms and reports are explained.

Keywords
Data analysis • Information • Data marts • Business intelligence

Introduction

Modern technologies infiltrate into almost all fields of the human activity. Data warehouse and data mart is a consolidated repository of structured data. Serving Business Intelligence (BI hereinafter) analytical tools that can draw data for analysis from data warehouses or data marts [1]. Data marts are thematically oriented data warehouse designed to mediate information to a department of the organization or geographic location. The difference between data warehouse and data marketplace is determined on the basis of occupied disk space, data warehouse takes order of magnitude larger disk capacity than the data mart.

At the present time Business Intelligence is one of the branches under the most rapid development. The underlay provided by it serves to the support of the objective and qualified decision-making. That is the reason why it has been applied in many different establishments [2, 3]. The BI under data warehouse provides two ways of displaying data. The first way is to view reports using the Report Server, which is part of the MS SQL server. Reports are intended for ordinary users, without detailed knowledge of data and data structures. These reports are output reports prepared by the programmer in the authoring environment. The second way is Online Analytical Processing (OLAP hereinafter) data analysis. This method of displaying information requires the detailed knowledge of data and data structures. For both ways it is necessary to create a relational and analytical database before the presentation of information as in [4, 5].

In the article we will describe data warehouses of unnamed company, which includes data warehouse Economy, Personal transport data mart and Prints data mart. A data warehouse is built on Microsoft technologies, specifically Microsoft SQL Server 2008 Standard [6]. Personal transport data mart is provided for users to view information about their underlying business trips, but also for detailed analysis of data. Data mart provides information to employees based on their inclusion in hierarchical organizational structure, i.e. managers can also view information about the business trips of their subordinates. Information's from the data mart are used to support approval process for business trips and allocation of official vehicles.

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_64,

Business Intelligence

Business Intelligence is a set of concepts and methodologies to improve decision making process using metrics or metrics based systems. The purpose of the process is to convert large volumes of data to knowledge that are needed for the end user. This knowledge can then be effectively used for example in the decision process and can form a very important competitive advantage.

The Main Functionalities of BI

- Data analysis
- Reports—list of tables and graphs
- Dashboards—interactive panels
- Data Mining—mining in data
- Corporate Performance Management (CPM)
- Predictive analysis

Components of BI

- Data Marts—DMA
- Data Staging Area—DSA
- Operational Data Store—ODS
- Enterprise Application Integration—EAI
- Data Mining
- Tools for metadata managing
- Tools for data quality insurance

Data Transformations

Data acceptable for next analysis have to be extracted from operational systems and put into data store. After that we can perform analyses by the help of OLAP technology, Data Mining technology or by the help of reporting services to create reports. This action is at the creation of data stores most important as well as more exacting. It is necessary to ensure analysis technologically heterogeneous data sources and then choose relevant data and centralize, integrate and aggregate them each other. This process is sometimes referred to as the data pump. Data pumps serves to collection and transmission of data from source systems to data stores and dumping ground.

They include:

- ETL process for extraction, transformation and transmission of data,
- EAI process for application integration (works in contrast to ETL tools in real-time).

ETL Process

ETL process starts by data extraction from primary sources (extraction). During this phase there are seek out and remove various data inconsistency. After the extraction follows data transformation (transformation) which will convert data obtained from single data sources into unified data model. The final phase of ETL is data transmission from source data memories or temporary dumping ground to database tables of the data store. At the primary filling it can be a gigantic quantity of data. By reason that ETL process works in batch mode next regular updating brings only such amount of data which corresponding with used time period (day, week, month, year).

EAI Process

ETL is an abbreviation of the extraction, application, and integration. EAI tools are exploited in source system layer. Their aim is integration of primary business systems and reduction of a number of their reciprocal interface. These tools work on two levels:

- at the level of data integration where there are used for integration and data distribution
- at the level of application integration where there are used for sharing of selected functions of information systems

Data Stores

The philosophy of data store (warehouse) has published for the first time by Bill Inmon in [8] (first edition was published in 1991). Genuine reason of data warehouse occurrence had connection especially with massive setting of server business systems and their conception of separate and independent application at the end of eightieth years of last century.

Data warehouses are special types of databases, which contain consolidated data from all accessible service systems. There are not optimized for quick transaction processing but quick administration of analytical information obtained from big amount of data. Data warehouses ensuring processes of storing, actualization and administration of data. There are exists two types of basic data stores and two types of auxiliary stores as in [8, 9].

Basic Data Stores

– Data Warehouse (DWH) PC
  Data warehouse is wide (extensive) central database in which are saved transformed data coming from various

service systems and external databases. Mentioned data are intended to following analyses.

– Data Marts (DMA)
  The principle of data marts is similar as the principle of data warehouses. Difference is only in one point of view—data marts are decentralized and thematic oriented.

Auxiliary Data Stores

- Operational Data Store (ODS)
- Data Staging Areas (DSA)

Online Analytical Processing

OLAP is method, which works with multidimensional databases that include data structures and analytical tools designed for analysis of large amounts of data. The result of analysis and aggregation of data is usually multidimensional data structure, called an OLAP cube. The basic building blocks for creating OLAP cubes are the facts and dimensional data as in [10, 11].

Fact Data

Fact data are numerical values of quantities; these quantities can be primary or may be calculated from other fact data. The fact tables are stored and analyzed fact data. These are values that we are monitoring and using for analytical calculations, sorting and aggregations. In connection with the fact data is using the term granularity, which determines the depth of the data details stored in fact tables. Lower granularity allows more detailed analysis, but increasing amount of stored data. There are much more data in fact tables than in the dimensional tables.

Dimensional Data

Dimensional data are information's about the values stored in fact tables. They contain information about the hierarchical, logical and organization data structure. Using the dimensional tables we usually ask questions when, where, why and etc. In comparison with the volume of fact data tables these are usually much smaller. There are often used hierarchical (tree structure) registration data as a dimensional data. A typical example of such data is date range or geographic dimension.

Approval Processes

Request for a Business Trip

Analysis of the requirements for passenger transport system functionality required identifying and describing the approval process for a business trip request. The main requirement was to fill a minimum amount of data to application and the maximum amount of data take up from the other systems. The flowchart of such approval process is shown on Fig. 1.

The approval process applications for a business trip can be done repeatedly.

Business Trip Statement

The business trip billing is possible only on the basis of an approved request form.

It can be possible to charge several business trips in one statement. Compensations for travel expenses are calculated

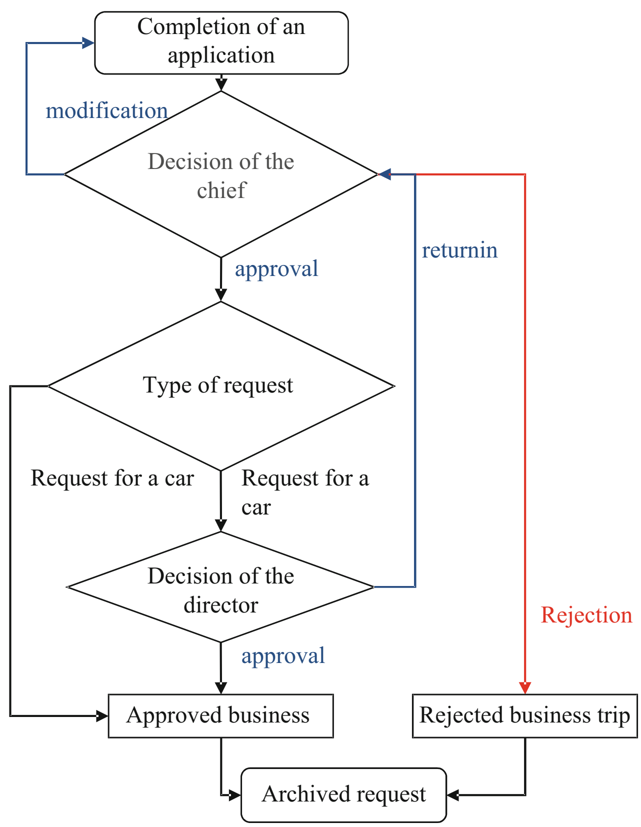

Fig. 1 The approval process of request for business trip

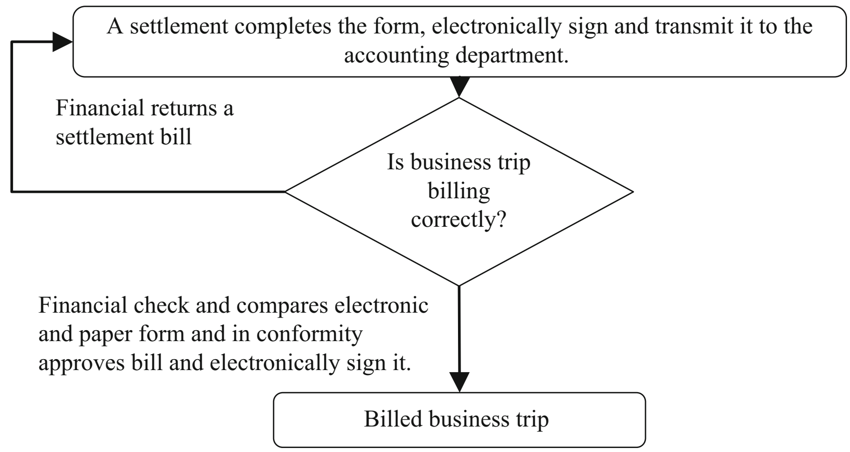

Fig. 2 The approval process of business trip statement

based on the entered data. Flowchart of business trips statement is shown on Fig. 2.

Requirements for Data Market Functionality

Data mart is intended for all staff within the organization. Information access is hierarchically structured in terms of organizational structure. There are available only limited information to ordinary workers, to managers are available extended information and data of their subordinates. To defined group of users are available all information [12]-[14].

Requirements of the original data mart:

- The data will be periodically transmitted from the data store to BI at least once a day.
- Will be created a logical and physical data model of data marketplace in accordance with established rules.
- Will be created ETL processes of data marketplace in accordance with established rules.
- Will be created multidimensional OLAP cubes in accordance with established rules.
- Will be created reports in accordance with established rules.
- It will set the security policy and security documentation will be updated.

Personal Transport Data Mart ETL Process

ETL process includes the extraction, transformation and storage. There are often problems with:

- Violation of referential and domain integrity
- Duplication of data with very poor identification of possible duplicates
- Absence of dials, or their misuse
- Random errors
- The problem of varying dimensions

The main task of the ETL process is to select the necessary data, clean them and ensure data integrity and localization in time. When creating a data warehouse relational database it is appropriate to use the basic principles:

- First load data from source information systems to 0th level data warehouse database.
- Then do the cleaning, transformation and loading to 1st level data warehouse database.

ETL process of personal transport is shown in Fig. 3. The first level is used for multidimensional data model within there are designed OLAP data cubes for data warehouse and data marts. Data from this level can also be used for reports. Data from the Personal transport information system will be regularly pumped into the data warehouse daily.

Zeroth Level Data Warehouse Database

The main task of this level is to copy data from source systems into the data warehouse database. It means a few steps:

- Creation of copied tables in the data warehouse database
- Conversion of data types when copying (Conversion of data types is necessary especially in case of copying data from database systems of different manufacturers, or file types csv, xls, txt and others)

These steps are created in the tool called Intelligence Business Development studio. So-called SSIS packages are used for ETL processes creation. When the ETL process is creating the whole process should be divided into several packages that are logically connected, due to clarity and starting times (Fig. 4).

First Level Data Warehouse Database

The main task of the first-level data warehouse database is to create a database for OLAP cubes and report server. It creates suitable group of records from the previous level at this level in the desired granularity. Granularity is word for particularity of observed records. Granularity in presented data marked is at the level of person's trip, individual prices,

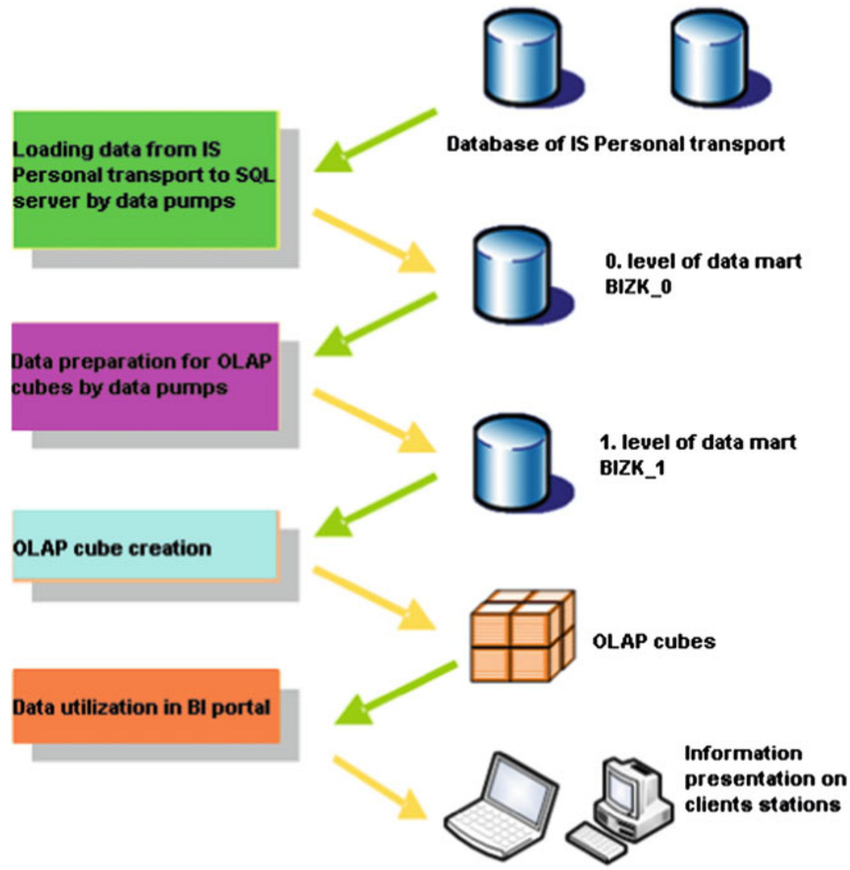

Fig. 3 Principle of personal transport data mart ETL process

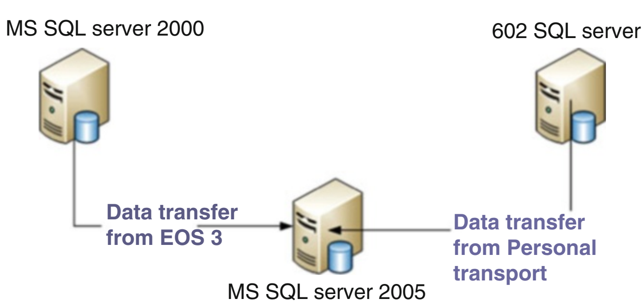

Fig. 4 Schema of database server's connections and copying the source data to 0-th level data warehouse database

etc. It is appropriate to create records in terms of dimensional and fact data at the same time (Fig. 5).

Extension of SQL Query for Data Transfer

Another modification of ETL process is interlacing the columns of source tables to columns of target tables. It was needed to assign corresponding columns in the mapping setting. Assignment of source columns with the target columns is performed automatically in the case that they have the same name. This fact could help us in defining the data model. On the other hand, it could bring errors in automatic interconnection of the source and target columns with the same name, which contains other data.

The Modified ETL Process Testing

Business Intelligence Development Studio (BIDS) allows testing SSIS package after creating or editing ETL process. Calling the context menu for the selected package can make it and using item Execute Package. BIDS is automatically switched to the Control Flow after confirmation of this option. On the Control Flow are displayed particular jobs. Jobs are color-coded according to the processing status:

- White background color—the job is not processed yet.
- Green color background—the job has been completed.
- Yellow background color—the job is processed now.

Automatic running of different packages (after creating and testing them) is ensured by means of two steps:

- Import package in Integration Services MS SQL.
- Create job in the Database Engine MS SQL server (determination of packages order and setting the time interval job's implementation).

Both steps are performed in SQL Server Management Studio, which allows connecting to several "Server type":

- Database Engine
- Analysis Services
- Report Services
- Integration Services

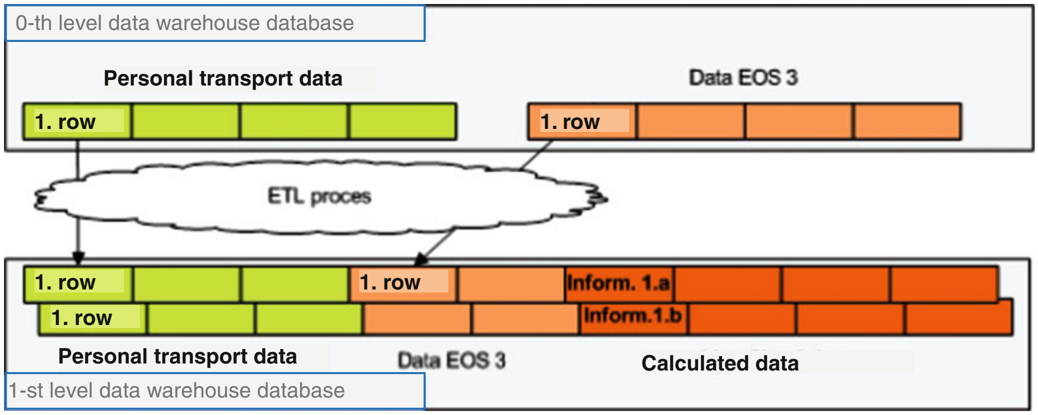

Fig. 5 Schema showing the extraction and transformation of data from level 0 to level 1

Auto Startup of ETL Process on SQL Server

After creating and testing packages it needs to run them automatically. Two steps can achieve this:

- Import the package in Integration Services MS SQL.
- Create job in Database Engine MS SQL server, determinate the running order of packages and set the time interval of job implementation.
- Both steps are done in SQL Server Management Studio, which allows connection to several server types.

Import of Packages to Integration Services MS SQL

Import of packages is done in Integration Services. In the Stored Packages folder are displayed already stored packages. With the context menu "Import package" new package is imported. It must be completed:

- Package location:
  - SQL Server
  - File System
  - SSIS Package Store
- Server—makes sense only with selection "SQL Server"or SSIS Package Store
- Authentication:
  - Windows Authentication
  - SQL Server Authentication
- Package Name

OLAP Cubes

We dealt with ETL process of creation a relational database in zero and first levels in the previous chapter. We can design and create a multidimensional database which draws data from the first-level relational database after this step.

Two above-mentioned kinds of databases differ in a way of data storage. We are trying to create the highest normal form when creating a relational database, but in a multidimensional database we mainly use non-normalized tables. OLAP cube always contains facts and dimensional attributes.

Creating of OLAP cubes is done in MS Business Intelligence Development Studio, which has already been used to create and modify the ETP process. OLAP cube is created in the following order:

- Data Sources
- Data Source Views
- Cubes
- Dimension

OLAP cubes are attached as a data source of BI portal where are stored basic views.

Reporting Services

The role of reporting services is to provide in an appropriate form and in time data for decision support at all levels of organizational infrastructure. The main reason for the deployment of reporting services is generating outputs in electronic or paper form. It allows employees at all positions effective access to data and thus supports them in their activities.

Reports can be divided according to the criteria of "control—adaptation reports" on two variants:

- Static—report shows the preset information displayed content cannot control. These reports are different from hard copy.
- Interactive—reports show the information that you can adapt by using of special elements (filters) to meet current need.
- Another criterion of the distribution is "field of philosophy and reports deployment":
- Enterprise—present data in business informatics.

- Embedded—report generation is an integral part of the application.
- B2B (Business To Business)—report generation for business partners.
- Hierarchy of staff reporting services distribution [5]:
- Consumers of information—the largest group that receives mainly extracts data in the form of simple reports.
- Workers actively working with the information—are able to analyze and process data. In this group of reporting tools are used and to some extent, analytical tools.
- Analysts—the smallest group of users, but in terms of expertise at the highest level. Their main task is to define new areas of requirements analysis, to analyze existing data support the interpretation of analyzed data used in decision-making process. Based on current trends, they are able to predict trends for the future. They use analytical tool.

It is appropriate to define the life cycle of the report when creating it. Life cycle of report consists of three basic phases:

- Draft report—it can be divided into other sub-phases:
  - Collection and evaluation of requirements,
  - Creation of reports in BI Development Studio (result is an XML file in the Report Definition Language—RLD). At this stage it is necessary to define:
  - Data Source,
  - Design of query,
  - Design of graphic look.
- Report management.
- Repot delivery—the method of delivery and format of the report is solving in this phase. The user can deliver reports on demand, or according scheduled tasks sent by email.

New Report Creation

Based on the monitoring of costs arose request to create a new report. This should display information about the compensation paid for the organizational units in individual years. Report should allow subdivision users in organizational units and months in selected years. Reports were created in BIDS development environment using the wizard.

In the first step of the wizard, we must select a data source (Data Source). In the next step (the Query Design) is necessary to define the SQL query. It is possible to write directly Query string entries, or use the Query Builder.

On the next screen (Select the Report Type) we can select the type of report:

- Tabular—classic display
- Matrix—matrix display

After selecting the type of report we need to define the other items in the next screen (the Design Matrix):

- Page
- Columns
- Rows
- Details

It is necessary to define the order of multiple items.

The last step is selection of reports style visualization. Development Studio allows to view and test the created report before placing in the report server. Testing is done in the “Preview” tool.

Each report displays a menu that allows:

- Paging report
- Increase or decrease the displayed report
- Search
- Data export

Reports for Employees

The first sample report is the report Travel orders for employees showing of all information (years, places, accounts etc.) obtained by clicking on “Extract All” as you can see on the Fig. 6.

Reports for Compensation Paid

Example of sample report aggregate amounts paid by organization from 2008 to 2010 for compensation paid is shown on the Fig. 7.

Conclusion

The experience with the application of the Business Intelligence and launching the data warehouses and data marts confirm the big benefit for the processes of the decision-making. Data market through user-friendly interface, opening up important and necessary information to all employees. Most important task was to provide managers with a tool for managerial decision-making and show further possibilities of this technology.

Additional requirements to extend the functionality of the data market, as well as passenger information system appeared during the work. The most important of them is the request to create a new data market of the organization structure that would include the information on the users, functional locations and their inclusion into the organization structure. These data markets should serve not only to managers as the basis to make decisions about these areas, but also to all subjects providing the data.

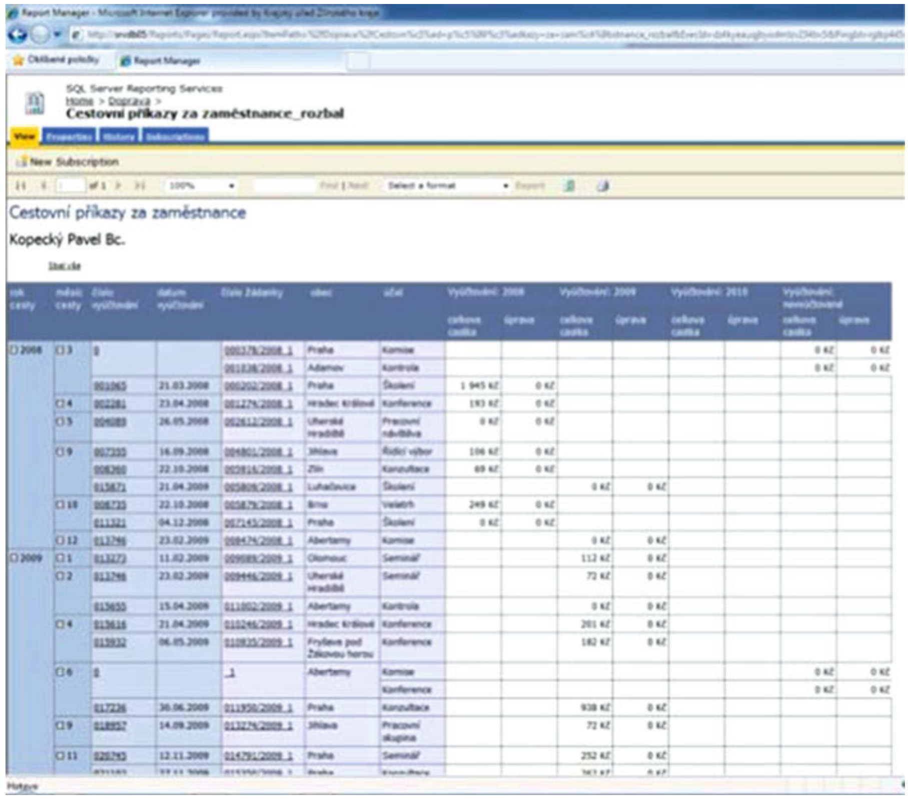

Fig. 6 Sample report—Travel orders for employees

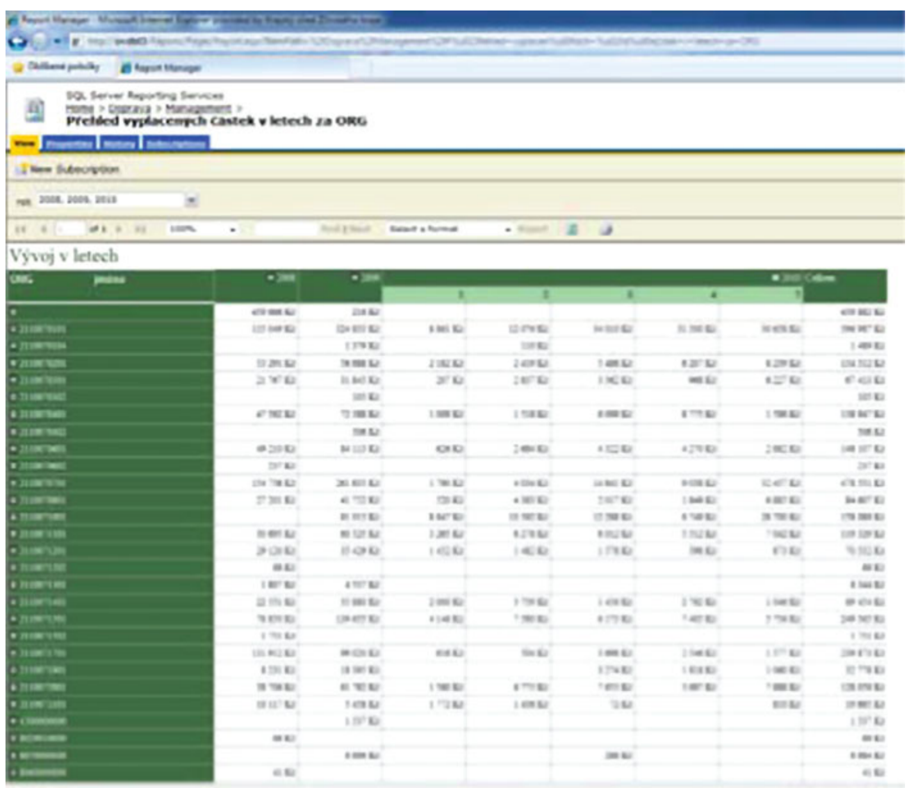

Fig. 7 Sample report aggregate amounts paid from 2008 to 2010

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Exact Algorithm for Matrix-Based Multilevel Project Planning Problems

Zsolt T. Kosztyán

Abstract

Besides network planning methods matrix-based methods can also be used in project planning and scheduling. In this case either importance or probability of task completions can be described, and thus either importance or probability of possible project scenarios and project structures can be determined and ranked by their importance or probabilities. When using matrix-based project planning methods the main challenge is to select the project scenario and project structures regarding the management claims. This approach can also be applied, if a most desired/most probable project portfolio or a multi project has to be specified instead of a single project planning. In this study fast, exact algorithms are introduced in order to select the most important project scenarios or the least cost/time demanded project structures. The new algorithm is a framework algorithm, which can be a fundamental basis of a project expert system and decision-makings.

Keywords

Project planning methods • Decision-making tools • Project expert system • Multi projects

Introduction

The most frequently used, traditional project planning methods like: network-planning [1–3], methods, Gantt charts [4], Line of Balance methods [5] primarily support the operative tasks of the project planning. If there is an accepted logic plan, where tasks and the dependencies between tasks are determined, we can schedule tasks, and we can allocate costs and resources by using different kinds of network planning, cost and resource allocation methods [6]. However, these algorithms have slight support for decision-making problems such as:

- Which tasks or subprojects should be selected into a new project?
- If there is not a strict technological order between tasks, which is the best sequence of the tasks regarding time, resource and cost demands of the project?

In the present case matrix-based methods can be used for support logic planning [7] instead of traditional project planning techniques. Thus the main challenge is to select possible project plans and to order them according to management claims. Up to the present there were no fast and exact algorithms to select and order first n possible project plan.

The scope of this study is to introduce new algorithms to select the best n piece (either most probable, shortest duration or lowest budgeted) project plan according to (time/cost/resource) constraints.

The aim of this research is to specify a novel algorithm for ranking different kinds of project scenarios and select the most adequate project plan which satisfies management claims.

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_65,

Background of the Study: The Evaluation of the Matrix-Based Project Planning Methods

The first matrix-based method used in project planning was published in 1981 by Steward [8]. Although, this method was originally used in production planning, it can also be used for modelling project plans.

Three main types of connections between activities are defined in this Dependency Structure Matrix Method (DSM): parallel, sequential, and iterative relations between two tasks (see Table 1). Sequential relation means task B can be started, if task A has been finished. Iterative relation means that after finishing task B, task A may be implemented again.

At first sight we cannot sense the novelty of this approach. Parallel and sequential connections are used in Critical Path Method (CPM) [2] and Program Evaluation and Review Techniques (PERT) [9] methods as well and Graphical Evaluation and Review Technique (GERT) [10] method can also handle cycles. But if we get a deep understanding of the research of matrix-based methods we can find some considerable methods for finding and handling cycles in the project plan (see [11]). One of these methods is partitioning, the other method is clustering, which can be used for finding quasi-independent subprojects. This method can be used for managing larger projects. Figure 1 below shows the results of clustering [12, 13].

Large projects can represent sparse matrices, where scheduling can be run with quasi-linear time demands [14].

However, these so-called Binary Dependency Structure Matrix (BDSM) representations can be used to describe strict relations between activities, there are Numerical Dependency Structure Matrix (NDSM) representations [15] for describing the strength and with stochastic network planning method (SNPM) for describing probability of the relations between two tasks [16].

With my colleagues we extended the SNPM method [7, 17], where probabilities or priorities can also be assigned to the completion of the tasks. If the probability or priority of the completions/relations cannot be estimated the completions/relations are uncertain (denoted by "?" in the Table 2). This representing method is the Project Expert Matrix (PEM).

Possible projects can be determined in two steps. First, we should decide which tasks should be implemented.

Table 2 shows that the completion of Task B was uncertain. Therefore, two SNPM matrices or ***project scenarios*** can be defined, where Task B is executed and where Task B is ignored. In the second step if we decide that Task B will be completed, we should decide how to execute these project scenarios: parallel or sequential. So, we can say that there are two ***project structures***. If Task B will not be completed, the question of 'how to complete Task A and Task B' is irrelevant, therefore only one project structure exists, where we complete only Task A.

When priorities or probabilities can be estimated project scenarios and project structures can be ranked. In spite of the fact that there are k uncertain task completions there are 2^k different kinds of project scenarios, a fast exact algorithm for ranking project scenarios and project structures are developed, called Agile Project Scheduling (APS) [14].

If matrix-based approach is used in project expert system for choosing a project plan according to strategic claims, we should extend the project expert matrix and the ranking algorithms, too. In case of probabilities or priorities the APS method is a fast exact method for ranking project scenarios and project structures, and other counting algorithm [14] can be defined for different kinds of target function, like finding minimal duration time or minimal total cost of the project etc., in strategic decision-making complex target function should also be considered, where minimizing time, cost and resource demands are equally important. Thus genetic algorithm will be used for ranking project structures and project scenarios instead of using exact or counting algorithms.

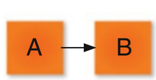
Instead of tasks we can consider projects or subprojects in the rows/columns of the PEM matrix for characterizing a multi project, a project portfolio or a programme. In this way multilevel PEM matrices can also be defined similarly to defining multilevel project networks. If completions of the tasks or (sub) projects are depending on each other than we will use Boolean (and, or, exclusive or (xor) etc.) operators for characterizing the dependencies of task/subproject completions. This matrix-based approach will be the ***extended Project Expert Matrix***: xPEM [18].

Rows/columns of the top-level xPEM matrix represent projects/subprojects of a multi project/project

Table 1 Possible relations between Task A and Task B

Sequential completion

	A	B
A		X
B		

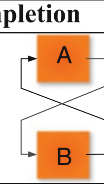


Parallel completion

	A	B
A		
B		

Iterative completion

	A	B
A		X
B	X	



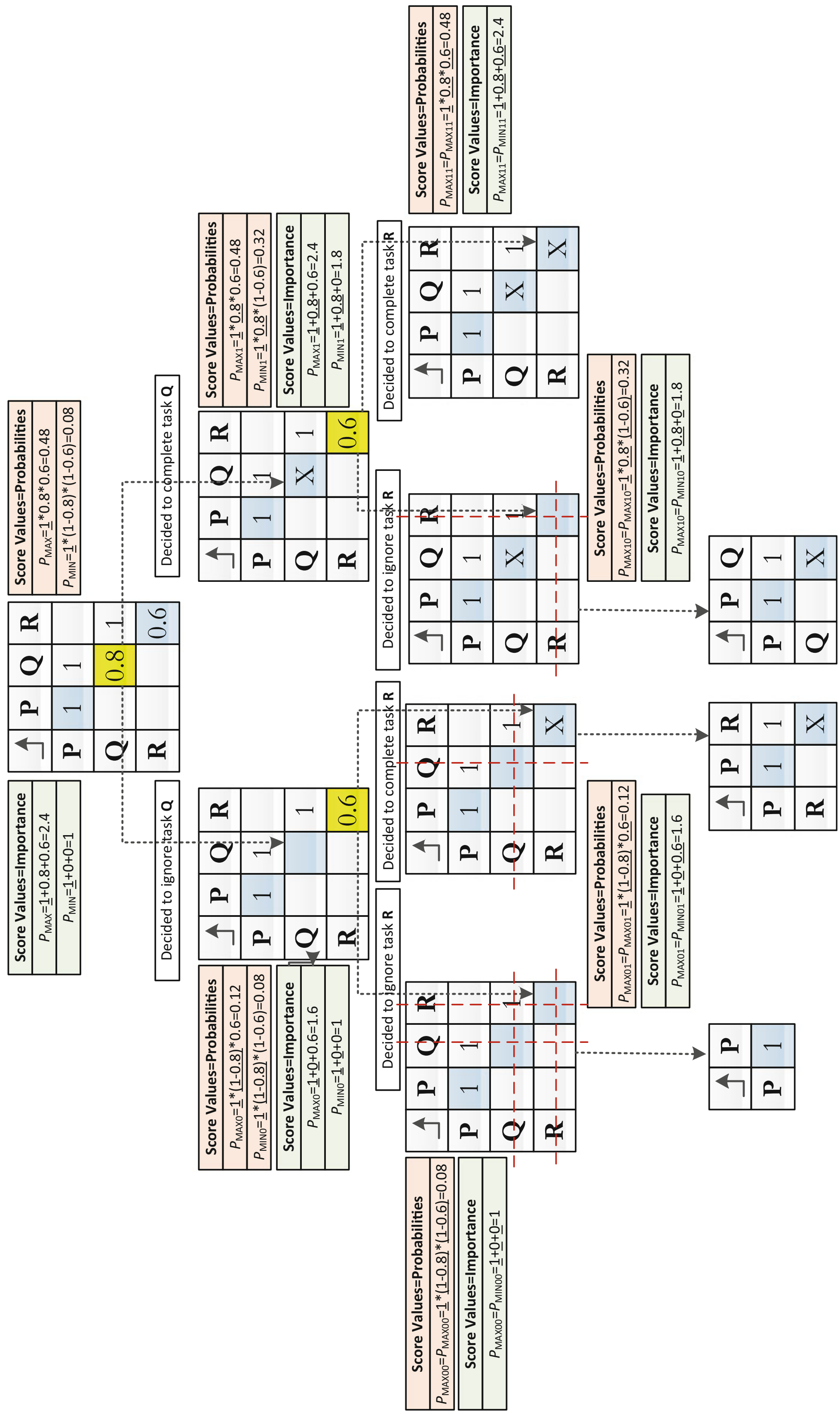


Fig. 1 Solving tree: specifying possible project scenarios

Table 2 Evaluation of matrix-base methods

<table>
<tr><th>PEM</th><th>NDSM/SNPM (Project Scenario)</th><th>DSM (Project Structure)</th><th>Activity-on-Node (AoN) Network</th></tr>
<tr><td rowspan="3">$\begin{array}{c|cc} & A & B \\ \hline A & X & ? \\ B & & ? \end{array}$</td><td rowspan="2">$\begin{array}{c|cc} & A & B \\ \hline A & & ? \\ B & & \end{array}$</td><td>$\begin{array}{c|cc} & A & B \\ \hline A & & X \\ B & & \end{array}$</td><td>A → B</td></tr>
<tr><td>$\begin{array}{c|cc} & A & B \\ \hline A & & \\ B & & \end{array}$</td><td>A
B</td></tr>
<tr><td colspan="2">$\begin{array}{c|c} & A \\ \hline A & \end{array}$</td><td>A</td></tr>
</table>

Table 3 xPEM matrices of a project portfolio, multi project, programme

Project portfolio

Budget	S_3	S_1	$S_4 \rightarrow S_2$	S_2	RG
4 m€	1	1			A
2 m€		.7			A
4 m€			.8	.6	B
2 m€					C
Dur.	2	3	3	1	*CPM*

Multiproject

Budget	S_3	S_1	$S_4 \rightarrow S_2$	S_2	RG
4 m€	1	1			A
2 m€		.7			B
4 m€			.8	.6	B
2 m€					C
Dur.	2	3	3	1	*CPM*

Programme

Budget	S_3	S_1	$S_4 \rightarrow S_2$	S_2	RG
4 m€	1	1	1		A
2 m€		.7			B
4 m€			.8	.6	B
2 m€					C
Dur.	2	3	3	1	*CPM*

S1–S4 are the IDs of subprojects
RG resource group, *CPM* Chief Project Manager

portfolio/programme. Budget, time and resource demands, score of the completion priority can be assigned to the subprojects. After clustering the top-level xPEM matrix different kinds of quasi-independent projects can be defined. In Table 3 three top level xPEM matrices are characterized. The first matrix represents a project portfolio, where projects are independent from each other (i.e. a product developing projects). The second matrix represents a multi project, where resources are common (i.e. construction multi project or a software developing project). The third matrix represents a programme or a mega project, where projects are depending from each other (like organizing the Olympic Games).

Probabilities/score of priorities of completion are described in the diagonal of the matrix, where 1 means certain completion. The first project contains S_1 and S_3 subprojects that are competed sequentially, if Chief Project Manager (CPM) selects S_1 for completion. When probability/score of priority of completion subproject S_1 is 0.7, we can assign $1 - 0.7 = 0.3$ probability value/score of priority to ignore subproject from a project portfolio/multi project/programme.

Boolean operators can also be used for characterizing dependencies for subproject completion. $S_4 \rightarrow S_2$ means that we can complete subproject S_4 and S_2 or ignore subproject S_4 and S_2, but if we select for completion subproject S_4, we also have to complete S_2, or if ignore S_4 we will also ignore S_2. "→" is the operator of implication; however, other Boolean operators can be used for characterizing dependencies of the completion. The result of selecting subproject S_4 for completion implies the result of selection subproject S_2 either probability or score of priority assigned to the subproject S_4. Either score of priority or probability of the project portfolio/multi project/programme scenario can be calculated by multiplication of non-zero probabilities/score of priorities of the subprojects. Above diagonals either probability or score of priority of relations between two subprojects are represented, where 1 means a certain relation between two subprojects. If either probability or score of priority of the relation between tasks are 0.6, we can say that the probability/score of priority of sequential completion is 0.6, and the parallel completion is $1 - 0.6 = 0.4$. As a result the probability/score of priority of project structure can also be calculated by the multiplication of the non-zero probabilities/score of priorities of relations between tasks.

Methods: Selecting Best Project Structures

Before selecting best (multi)project scenario or (multi)project structure according to a given target function possible (multi) project scenarios and (multi)project structures should be able to be compared to each other. Thus score values should be attached into the probable project plan. In this way project scenarios and project structures can be ranked by their score values. Score value can mean probability, importance, duration time, cost or resource demands of the possible project plans.

If there are time, cost and/or resource constraints infeasible project plans can be ignored regarding different kinds of score values.

For instance let the score value of task/project completion as either a probability value or an importance value. In the first case the goal is to specify the most probable, while in the second case the goal is to specify the most desired project scenario.

If PEM_{ii}, $(i = 1,..,n)$ is a diagonal element of an n by n **PEM** matrix, where n is the number of tasks/projects the maximal (P_{MAX}) and minimal (P_{MIN}) score value can be calculated as follows:

1. If uncertainty values can be described as probability values of the task completion:

$$P_{\mathrm{MAX}} = \prod\nolimits_{i=1\ldots n, P_{ii}\in\left]0,1\right[} \begin{cases} P_{ii}, \text{ if } PEM_{ii} = 1 \\ Q_{ii}, \text{ if } PEM_{ii} = 0 \\ \max(P_{ii}, Q_{ii}) \text{ otherwise} \end{cases}, \tag{1}$$

$$P_{\mathrm{MIN}} = \prod\nolimits_{i=1\ldots n, P_{ii}\in\left]0,1\right[} \begin{cases} P_{ii}, \text{ if } PEM_{ii} = 1 \\ Q_{ii}, \text{ if } PEM_{ii} = 0 \\ \min(P_{ii}, Q_{ii}) \text{ otherwise} \end{cases}. \tag{2}$$

2. If uncertainty values cannot be described as probability values (i.e. uncertainty = utility or importance) or sum of score values (sum of utilities) of task completion should be maximised/minimised:

$$P_{\mathrm{MAX}} = \sum\nolimits_{i=1\ldots n, P_{ii}\in\left]0,1\right[} \begin{cases} P_{ii}, \text{ if } PEM_{ii} = 1 \\ Q_{ii}, \text{ if } PEM_{ii} = 0 \\ \max(P_{ii}, Q_{ii}) \text{ otherwise} \end{cases}, \tag{3}$$

$$P_{\mathrm{MIN}} = \sum\nolimits_{i=1\ldots n, P_{ii}\in\left]0,1\right[} \begin{cases} P_{ii}, \text{ if } PEM_{ii} = 1 \\ Q_{ii}, \text{ if } PEM_{ii} = 0 \\ \min(P_{ii}, Q_{ii}) \text{ otherwise} \end{cases}. \tag{4}$$

These values specify the maximal/minimal score value of a project scenario without determining all possible project scenarios.

Since there are only two decision results about task realisation, the decision tree will be a binary tree (see Fig. 1).

Maximal (minimal) score value (P_{MAX} (P_{MIN})) are on the top of the tree. In any other layers maximal (minimal) score values (P_{MAX0}, P_{MAX1}, P_{MAX00}, $P_{\mathrm{MAX01}\ldots}$ (P_{MIN0}, P_{MIN1}, P_{MIN00}, $P_{\mathrm{MIN01}\ldots}$)) are not greater (not lower) than the P_{MAX} (P_{MIN}) value. In the second level there are two child nodes, where maximal (minimal) score values (P_{MAX0}, P_{MAX1} (P_{MIN0}, P_{MIN1})) are the maximal (minimal) values considering their child nodes. The characteristic of this decision tree allows to create a branch and bound algorithm in a very easy way.

After deciding which tasks have to be completed, dependencies between tasks should be specified. While a diagonal value means either importance or probability value of a task completion, off-diagonal values can mean either probability or importance of dependencies between tasks. In one hand if score values of dependencies can mean as probabilities, the probability value of a possible project structure is calculated as a multiplication of probability values of dependencies between tasks. On the other hand if a score value of dependencies between tasks can mean as importance values or completion priorities than the total score value of a project structure can be specified. If there is no uncertain task completion **SNPM** and **PEM** matrices are identical.

Similarly to the maximal/minimal score value of project scenarios, maximal/minimal score values of project structures can be specified without the claim of calculating all possible project structures.

If $SNPM_{ij} = PEM_{ij}$, $(i, j = 1,.., n;\ i \neq j)$ is an off-diagonal element of **SNPM** = **PEM** matrix.

The maximal (p_{MAX}) and minimal (p_{MIN}) score value can be calculated as follows:

1. If uncertainty values can be described as probability values of the task dependencies:

$$p_{MAX} = \prod\nolimits_{i=1\ldots n, j=1\ldots n, i\neq j, p_{ij}\in\left]0,1\right[} \begin{cases} p_{ij}, \text{ if } SNPM_{ij} = 1 \\ q_{ij}, \text{ if } SNPM_{ij} = 0 \\ \max\left(P_{ij}, Q_{ij}\right) \text{ otherwise} \end{cases}, \tag{5}$$

$$p_{MIN} = \prod\nolimits_{i=1\ldots n, j=1\ldots n, i\neq j, p_{ij}\in\left]0,1\right[} \begin{cases} p_{ij}, \text{ if } SNPM_{ij} = 1 \\ q_{ij}, \text{ if } SNPM_{ij} = 0 \\ \min\left(p_{ij}, q_{ij}\right) \text{ otherwise} \end{cases}, \tag{6}$$

2. If uncertainty values cannot be described as probability values (i.e. uncertainty = utility or importance) or sum of score values (sum of utilities) of task completion should be maximised/minimised:

$$p_{MAX} = \sum\nolimits_{i=1\ldots n, j=1\ldots n, i\neq j, p_{ij}\in\left]0,1\right[} \begin{cases} p_{ij}, \text{ if } SNPM_{ij} = 1 \\ q_{ij}, \text{ if } SNPM_{ij} = 0 \\ \max\left(p_{ij}, q_{ij}\right) \text{ otherwise} \end{cases}, \tag{7}$$

$$p_{MIN} = \sum\nolimits_{i=1\ldots n, j=1\ldots n, i\neq j, p_{ij}\in\left]0,1\right[} \begin{cases} p_{ij}, \text{ if } SNPM_{ij} = 1 \\ q_{ij}, \text{ if } SNPM_{ij} = 0 \\ \max\left(p_{ij}, q_{ij}\right) \text{ otherwise} \end{cases}. \tag{8}$$

These values specify the maximal/minimal score value of a project structure without determining all possible project plans. Considering the binary decision tree of project structures the project plans can be found in k steps, where k is the number of uncertainty dependencies (see Fig. 2).

```
function DSM:=BestDSM(SNPM,p,q):
   u:=false //Existance of uncertainty value
   for i from 1 to n:
       for j from i+1 to n:
           if SNPM(i,j)<1 and SNPM(i,j)>0 and i<>j then:
              u:=true
              SNPM_0(i,j):=0 //Left side
              maxs_0:=maxscore(SNPM_0,p,q);
              SNPM_1(i,j):=0 //Right side
              maxs_1:=maxscore(SNPM_1,p,q);
              if maxs_0>maxs_1 then: //Go to find maximal score value.
                 DSM:=BestDSM(SNPM_0,p,q)
              else: DSM:=BestDSM(SNPM_1,p,q)
              return
   if u=false then: DSM:=SNPM//Evaluated SNPM will be the best DSM
return DSM
```

Fig. 2 Find most probable (most desired) project plan

Using the construct of the solving tree (see Fig. 1), if probability values are different, and if the number of uncertain task is t and the number of uncertain dependencies is d then most probable (most desired) project plan within a most probable (most desired) project scenario can be calculated within $O(k + t)$ step. The first n most probable (most desired) project plan can be specified within $O(n(k + t))$ step.

Results: Simulations

The scope of this chapter is to test the algorithm in large, complex projects. If there is no uncertain task completion, the number of possible project structures depends on only the number of uncertain dependencies. If there are k uncertain dependencies then there are 2^k possible project plans. The project network can be specified as an SNPM matrix. If the project network does not contain cycle then the adjacency matrix of the project network can be specified as an upper triangle matrix. If there are n tasks, the maximal number of uncertain dependencies are $n^* (n - 1)/2$, and in this case the number of possibilities $2^{n^* (n-1)/2}$.

If there are t uncertain tasks, than 2^t project scenarios can be specified. In a special case when $t = n$, and $k = n^* (n - 1)/2$ than there are 2^n project scenarios and $\sum_{j:=0}^{n} \binom{n}{j} 2^{j(j-1)/2}$ project plans.

It is easy to build a matrix, which specifies a huge number of project scenarios and project structures: i.e. when a 10 by 10 PEM matrix contains $t = n = 10$ uncertain tasks and $k = n^* (n - 1)/2$ uncertain dependencies, the number of project scenarios is more than $3{,}588 \times 10^{13}$.

In the first simulation task different size of SNPM and PEM matrices were specified where every uncertain dependency/task completion was at the upper triangle/diagonal.

The goal was to select the top 1, 10, 100 and 1,000 project plans, where score values of the project plans are decreasingly sorted. Uncertainty value of dependencies are in]0,1[interval follows unified distribution. However, PEM contains uncertain tasks and uncertain task dependencies the number of possible project plans are very similar. Let $s := 2^k = 2^{n^* (n-1)/2}$ be the number of possible project plans in case of considering fulfilled upper triangular n by n SNPM matrix; $p := \sum_{j:=0}^{t} \binom{t}{j} 2^{j(j-1)/2} = \sum_{j:=0}^{n} \binom{n}{j} 2^{j(j-1)/2}$ be the number of possible project plans in case of considering fulfilled upper triangular n by n PEM matrix, where every tasks completion are also uncertain. Since $\lim_{n\to\infty} \sqrt{\log_2(s)} = \lim_{n\to\infty} \sqrt{\log_2(p)} = \sqrt{2}\left(\frac{n}{2} - \frac{1}{4}\right)$ the complexity of specifying project plans from SNPM and PEM matrix are similar. Also the computational demand of this algorithm $O(k) = O(n^* (n - 1)/2) \approx O(n^2)$ in case of considering fulfilled upper triangle SNPM matrix, and the run time $O(k + t) = O(n + n^* (n - 1)/2) \approx O(n^2)$ is similar when regarding a fulfilled upper triangle PEM matrix. In case of n = 50 a fulfilled upper triangle SNPM and PEM matrices specify $5{,}78 \times 10^{368}$ possible project plans. In this case the top 1,000 project structures can be specified within an hour applying a Pentium core 2 processor with 4 MB RAM.

In the second simulation cost and time demands are also generated randomised and followed unified distributions. The goal was to specify the top 10 most desired/most probable project plans from a 50 by 50 fulfilled PEM matrix,

Table 4 Simulation results, where every cells are mean value of 1,000 simulations

	TPT (90 %)		TPT (85 %)		TPT (80 %)	
	Number of ignored tasks	Number of ignored dependencies	Number of ignored tasks	Number of ignored dependencies	Number of ignored tasks	Number of ignored dependencies
TPC (90 %)	10.2	0.5	9.4	2.4	10.1	3.5
TPC (85 %)	14.9	0.1	15.1	0.6	15.4	1.2
TPC (80 %)	19.9	0.0	20.1	0.1	19.8	0.4

where every uncertainty value of task completion and dependencies was between]0.5,1[intervals, which means every task and every dependency should be realized. Cost and time demands of the project should have been decreased 10, 15 and 20 % (Table 4).

Summary and Conclusion

In this paper a new matrix-based project planning method was introduced. In the course of the evaluation three matrix-based methods are used: PEM for characterizing multilevel projects; SNPM for describing a project scenario and a DSM for presenting a project structure. Since there are huge numbers of variations of different kinds of project scenarios and project structures exact algorithm should be used for selecting adequate project scenarios and project structures considering management claims.

The introduced method is a fast and exact method to select feasible project scenarios and project plans within different kinds of projects. To apply score values the most desirable and, feasible project plans can be selected taking time, cost and resource constraints into consideration.

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Operation of a Microgrid System with Distributed Energy Resources and Storage

Linfeng Zhang, Xingguo Xiong, and Junling Hu

Abstract

In a heat-power system, the use of distribute energy generation and storage will improve system's efficiency, reliability, and emission. This paper is focused on the operation of a microgrid consisting of a PV system, a hydrogen fuel cell stack, and a PEM electrolyzer. As a grid-tied system, there is a two-way power flow between the system and the grid. The microgrid generates electric power needed for the local electric load and heat for the local heat need. With the proposed performance indexes, the system under an electricity-led scenario is simulated. The price, emission, service quality, and the overall performance indexes are all between 0.8 and 0.9. Moreover, the electric demand is 100 % met and heat demand 45.8 %.

Keywords

Fuel cells • Hydrogen storage • Solar energy • Energy management

Introduction

In order to improve the efficiency, reliability, economics, and sustainability of power generation and distribution, the traditional power grid is being upgraded to the smart grid (SG). A SG includes new technologies in information and communications, in distributed energy generation (DEG) and distributed energy storage (DES), in advanced measurement and sensing, in controls, in cyber security, and in consumer-side energy management [1–6].

DEG is small-scale power generation with power less than 50 kW. It includes micro turbines (μturbine), micro combined heat and power (μCHP) systems, photovoltaic systems (PV), wind turbines, and solar thermal systems [7, 8]. Electricity and on-site heat can be produced near the point of demand, allowing for production of energy with high efficiency and avoidance of the transmission and distribution losses in the conventional centralized generation model [9–11]. However, the widespread emergence of the DEG on the consumer side will significantly increase the variability of generation due to the intermittent nature of generators, especially wind turbines and photovoltaic (PV) systems. To balance supply and demand and to minimize the DEG-induced power fluctuations in the grid, compensating changes are required in the demands, DES, and output from flexible generation sources [12].

Scheduling freedom is important in the optimal operation of the DEG. The generation from renewables strongly depends on the weather. Thus, the operation of the wind turbine, PV system, and solar thermal system has no scheduling freedom. However, μturbine and μCHP are controllable but with some limits. The μturbine can also be regarded as a special case of μCHP but without waste-heat recovery.

In a μCHP, heat and electricity generation are coupled. Thus, there are three operating strategies: heat-led, electricity-led and cost-led. For the first strategy, the CHP system is controlled to meet the onsite heat demand as much

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_66,

as possible with electricity as a byproduct. For the second strategy, demands for local electricity must be met. The third strategy is to minimize the cost. The operating point is related to the power via the heat ratio, and this can be used to estimate the efficiency. The control strategy can be totally different when electricity and heat generation can be decoupled in the presence of heat storage.

Although common problems for a DEG are their high costs and non-dispatchable nature, their advantages are still obvious in high efficiency, high flexibility, and low emission. Since the local load includes thermal as well as electrical loads, μCHP systems, such as internal combustion engines (ICEs), stirling engines, and fuel Cells (FCs), are becoming more and more attractive [13]. However, there is no pattern of behavior to μCHPs. For instance, different fuel technologies have start-up times ranging from minutes to hours. Therefore, the operation scheduling for these generators must be made with the consideration not only of their operating costs and emission but also of their dynamic operating constraints. In addition, the stochastic DEG from renewables, such as PV systems and wind turbines, has significant negative impacts on grid voltage and frequency stability. In order to compensate for these, techniques in DES have been developed to mitigate this variability for short periods. Currently, DES includes rechargeable battery, super capacitor, and hot water tank technologies. They have different ratings for power and discharge time. Other energy storage technologies, like compressed air energy storage, hydrogen, and pumped-hydro storage are normally deployed in large scale with long discharge time up to days [13, 14]. The control strategies for DES will be based on the DES behavior, efficiency, and the energy conversion efficiency. Similarly, electrical and thermal demands in energy also have distinct characteristics, and they can be categorized into different types based on whether they can be trimmed in the peak period or shifted to the off-peak period. Thus, they can adjust their consumption levels to correct voltage sags and flickers or to help stabilize the system frequency.

Local DEG, DES, and active demand (AD) can be aggregated as a microgrid with a grid connection for import and/or export of electricity. One MG can run in two modes: grid-tied and islanded [15]. In the first mode, power is transmitted in two ways between a MG and the rest of the SG. A MG may consume the power from the other MGs or it may supply power to them for credits according to the agreement between this MG and a local utility company. In an islanded mode, intentional "islanding" under certain circumstances, provides local reliability, stability, and security. At the same time, this operation does not change or disrupt the integrity of the transmission grid as a whole [15, 16].

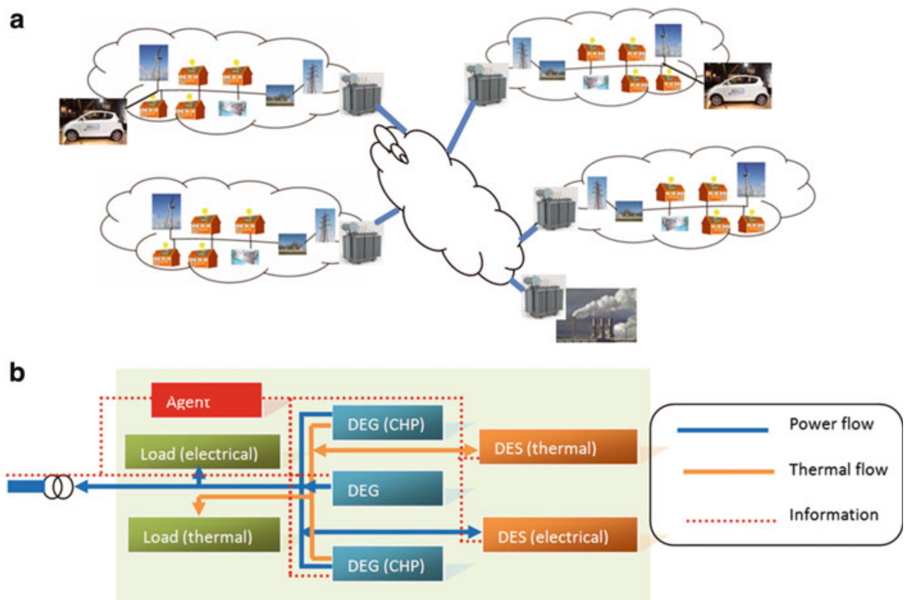
Generally, energy management for the consumer, means to minimize the cost of electricity. In a grid, the price of electricity is established by the market to balance sellers' supply and buyers' demand. This balancing process should be continuous and instantaneous, since electricity must be produced at nearly the same instant it is consumed. Market trades in electricity can be: (i) bilateral transactions—short-term forward market trading in the form of a day-ahead market, and (ii) spot market trades in real-time. The first is conducted between wholesale consumers and power plants, and it provides price certainty. But consumers with DEG, DES, and AD must pursue a combination of short-term trading and spot trading. Thus, in order to maximize their benefits from the generation and consumption, consumers can balance their portfolios and adjust their generation or demand under some short-term predictable and unpredictable circumstances [12, 17].

With dynamic electricity price, two-way power flow, and two-way communication in a SG, consumer-side energy management needs to be developed for the consumers and key stakeholders to actively manage energy for a better, cost-effective service through the operation optimization of their DEG, DES, and loads [18, 19]. This management will also facilitate the integration of emerging energy storage and renewable generation technologies within the power system.

In order to provide cost effective usage of energy and to alleviate the concern of power quality, effective consumer-side energy management includes the scheduling of demand, storage, and generation can be market-based controls and agent-based controls. The first emphasizes the creation of a competitive market environment for DEG, DES, and AD devices and the regulation of the production/consumption of DER with direct market signals in order to meet the perspectives on cost and effectiveness. Depending on the control structure, there are three different operations: direct control, price signal control, and internal exchange [13]. The agent-based control emphasizes the importance of device coordination and reliable communications with its neighbors. This system has scalability and optimization objectives; minimum cost, maximum profit, or highest efficiency [12]. Optimal control deals with the problem of finding a control law for a given system portfolio and forms the basis of other control strategies by providing mature mathematical theories and detailed optimization algorithms. In both cases, advanced metering infrastructure (AMI) is necessary to implement the system required to monitor the status of the devices. This also improves customer service, especially in power outage detection, grid operation, disaster recovery, and accuracy of load estimation; this is a result of information on the distribution grid collected near each consumer [20, 21].

As of now, there is no comprehensive framework for the development of consumer-side energy management. Controls are mainly used to minimize cost without consideration of a particular unit's behavior. It is necessary to derive

Fig. 1 The schematics of a power system (**a**) and a microgrid (**b**)



comprehensive system performance metrics and models for differing demands. Thus, a consumer-side energy management can be developed. In this paper, performance indexes and a general model are illustrated in section "Model", this model, a grid-tied microgrid, consists of a PV system, a fuel cell stack, an PEM electrolyzer, hydrogen tank, electric and heat loads. In section "Results and Discussion", the microgrid under electricity-led scenario is simulated with the result discussion.

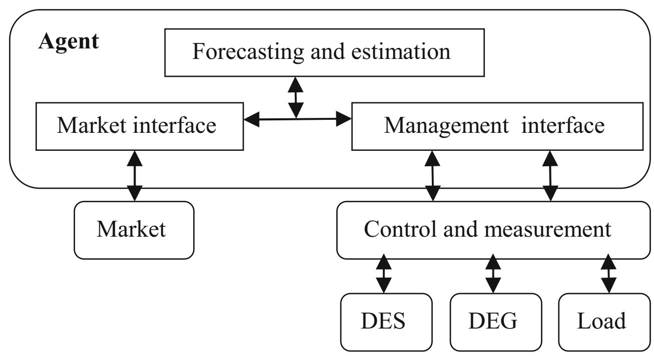


Fig. 2 The structure of an agent-based energy management system

Model

Figure 1a shows the power system consisting of multiple micrograms, each of which is a set of an agent, DEG, DES, and Loads. Among the microgrids, there are two-way power flow and communication. Figure 1b shows a basic structure of a microgrid. One agent in this sub-power system collaborates with the other agents on the grid to manage local energy generation, consumption, and flow. To minimize the communications overhead, a regional manager, an agent selected from multiple microgrids, will exchange information with the managers in a wide area. Therefore, the energy system is a distributed system while the communication is a hierarchy system.

The structure of agent-based energy management is shown in Fig. 2. The agent can be the weather forecast or the estimated energy generation/consumption pattern for a local DEG and loads for the upcoming time period. This agent communicates with its regional manager which is also an agent but voted by its neighbors to be the manager. The regional manager then aggregates the energy profiles and trade with the other managers through bids and auctions in order to balance the supply and demand and determine a price. A two-layer hierarchical structure will ensure scalability and reduce communication overhead. Thus, with the information from the regional manager, an agent can make a decision to optimize the operation of the system through real-time control with AMI.

Beside the economic return on the investment of an individual MG, a performance metric Q should includes the environment effect and the service quality for each MG:

$$Q = w_1F + w_2E + w_3S \tag{1}$$

F is a price index of electricity, E is an environmental effect (emission) index, S is the service quality of electricity and heat. Q, F, E, and S are all between 0 and 1. $w_i(i = 1, 2, 3)$ are weighting factors and $\sum w_i = 1$. The ultimate objective for each MG is to maximize its overall performance index. Although this performance index is introduced for one MG, it can be applied for an entire SG under certain circumstances. In this simulation, w_1, w_2, w_3 are set as 0.4,

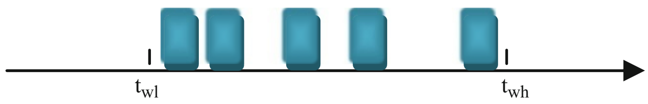


Fig. 3 Demand in an time window

0.3, and 0.3, respectively. The dynamic price of electricity from a SG central dispatch is assumed to be 3 units during peak times (between 8 o'clock and 18 o'clock), and it is 1 unit during off-peak times. The price of electricity from solar panels or FC stack is 2 units. Note, the price index may be more than 1 if the electricity from solar panels is much less than that from the grid during the peak hour. Therefore, the price index of electricity, F, can be calculated as:

$$F = \frac{c_{SG-off-peak}}{c_{avg}} \tag{2}$$

Here, $c_{SG-off-peak}$ is the price of electricity from a SG central dispatch in off-peak time and it includes the equivalent power cost for the heat generated by the fuel cell stack. c_{avg} is the average cost of electricity for a MG and it doesn't need to include the cost of heat from the fuel cell stack.

The electric/heat service quality can be calculated as:

$$S_1 = \frac{1}{T}\sum_{t=0}^{T}\sum_{i=1}^{3}\left(w_i\frac{P_{\text{supply},i}}{P_{demand,i}}\right) \tag{3}$$

Here, T is a period of time, and i is the priority of the load (high, normal, or low). $P_{\text{supply},i}$ is the energy supplied to the load demand with a priority i, and $P_{demand,i}$ is the load demand with a priority i. $w_i(\text{i} = 1, 2, 3)$ is a weighting factor for the load with priority i, and $\sum w_i = 1$. In this simulation, w_1' w_2, w_3 are set as 0.5, 0.3, and 0.2 for the loads with high, normal, and low priorities, respectively.

Demand can be categorized into different types based on whether it is can be shifted, interrupted, decreased, or canceled. It also has different priorities in the presence of limited supply. Generally, demand is a random variable with a probability distribution in an operation time window, and it can be regarded as a series of separated and fine-grained tasks, which means each task can be completed in a sequence but not in continuous time slots, as shown in Fig. 3.

With constraints, the demand is

$$PH_i = \sum task_i \tag{4}$$

$$t_{wl} < t_{task_i} < t_{wh} \tag{5}$$

The characteristic of any demand can be described in the above equations by occurrence probability, task number, and time window. In addition, the characteristic of a demand may change. For example, a heat load in a hot water tank can be interruptible and shiftable with low priority between midnight and early morning. Thus, it can provide enough hot water for showers in the morning. However, this hot load can be non-interruptible and non-shiftable with high priority if not enough hot water available in the morning due to extra guests. The charging of an electrical vehicle is similar to this.

An upper limit for the local total energy capacity, power or heat, is:

$$\sum PH_i < PH_{capacity} \tag{6}$$

The heat service quality is

$$S_2 = \frac{H_{\text{supply}}}{H_{demand}} \tag{7}$$

The air emission index is defined as:

$$E = 1 - \frac{e_{avg}}{e_{plant}} \tag{8}$$

where e_{avg} is the average atmospheric emission for electricity consumed in a MG, and e_{plant} is the emission from a fire power plant. In this paper, the emission is set as 3 units for electricity from the fire power plant and 0 unit for electricity generated from a solar panel or a fuel cell stack in a MG.

On the grid, the price of electricity is dynamic, based on the supply and demand. The day-ahead price can be forecast using wavelet transforms and related simulations [14, 22]. Although the price is mainly determined by the supply from the power plants and the major demand, it is can be affected by DER and AD. The agent only participates in day-ahead market or spot market. For each device, based on the historical energy pattern, a predicted energy profile is generated for the day-ahead trading using neural network techniques. The Mont Carlo simulation is utilized to generate scenarios for real-time uncertainties. In the management process, optimization objectives are different for the shareholders of the power system versus the consumers. For residents or microgrids, there is a tradeoff between energy cost, energy security, and environmental protection. For utilities, the objective is the maximization of profit. Utilities are more likely to generate electricity when the price is high. In each case, the performance index, Eq. (1), is applicable but with different weighting factors. The combination of marketing, prediction, and real-time control in one subsystem exploits all potential benefits derived from each period of time.

Figure 4 shows the structure of the micro-power system studied in this paper. The whole system includes a PV system, an electrolyzer, a hydrogen fuel cell stack. This system provides power and heat. Heat is only for the load

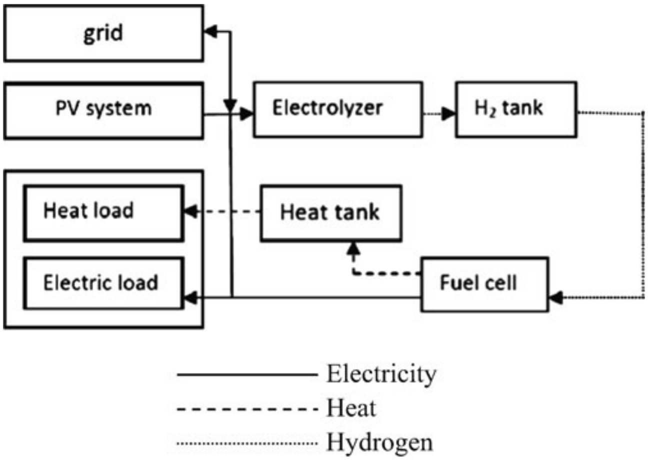


Fig. 4 The structure of the micro-power system

heat load which fluctuates with the environment temperature. In the day time, the power from the PV system will be used to meet the local power demand and then be stored as hydrogen through the electrolyzer. The rest will be transferred to the grid. In the same time, electricity can also flow from the grid to this system. In the night time, the stored hydrogen will be supplied to fuel cell stack, which generates power as well as the heat.

The model of the fuel cell stack is with the extra consideration in heat transfer and start-on delay.

The open circuit voltage of a single cell can be calculated with Nernst equation:

$$E = -\frac{\Delta \overline{g}_f^0}{2F} + \frac{RT}{2F}\ln\left(\frac{\alpha_{H_2}\alpha_{O_2}^{1/2}}{\alpha_{H_2O}}\right) \tag{9}$$

Where, $\Delta \overline{g}_f^0$ is Gibb's free energy at stand pressure, F is the Faraday constant, and α is the gas activity.

The activation overboltage is

$$\Delta V_{act} = a\log\left(\frac{i}{i_0}\right) \tag{10}$$

Where, i_0 is the exchange current density.

Other overvoltages due to internal current and Omic loss are also considered for simulation. For the turn-on delay, a time constant is added.

To operate the fuel cell stack only for electricity, the desired power is given. Except the maximum power, there are two operating points, cell voltage and current density, for the same power output on the CV curve. The selection of the operating point is based on the system requirements, such as lowest cost, lightest unit, highest power density. For example, a point at high current density make the cell small to lower down the capital cost, but its efficiency will be low

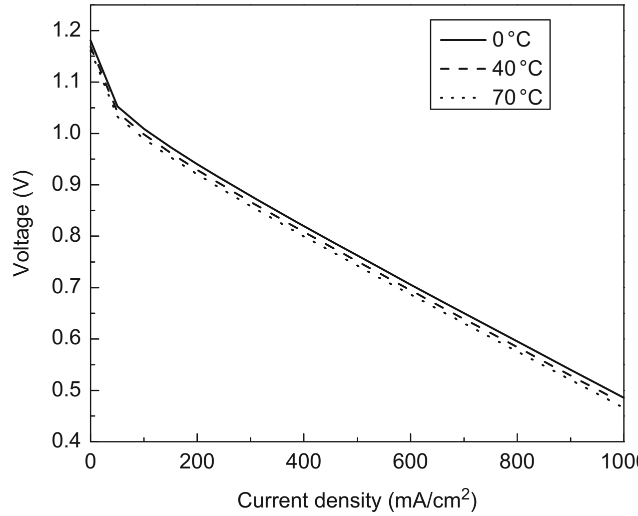


Fig. 5 The steady-state current density-voltage curves of the fuel cell at different temperature

with more heat generated. To use fuel cell stack as a CHP system, both the desired heat and power outputs are given, the operating point can be determined by the power/heat ratio if both points are allowed by the system.

In this simulation, the partial pressures of hydrogen and air are 2 atm and the current-voltage curves are shown in Fig. 5. As temperature increase, voltage drops a little. The operating of the fuel cell will be affected by the environment temperature.

Generally, a fuel cell stack as a μCHP supply needs to supply electricity and heat as:

$$h_{chp} + h_{other} = h_d \tag{11}$$

$$e_{chp} + e_{other} = e_d \tag{12}$$

Where, h_{chp} is the heat from the μCHP, h_{other} can be the heat from boiler, heat storage, and solar thermal system, e_{chp} is the electricity from the μCHP, e_{other} can be from a wind turbine, PV system, grid, and electricity storage, and e_d is the demand. Electricity from the grid is positive when power flows from the grid and negative when power flow into the grid.

The constraint on the μCHP's generation is

$$PH_{cap_l} < PH < PH_{cap_h} \tag{13}$$

where, PH is power or heat and PH_{cap_l} and PH_{cap_h} are the lower and upper limits.

The fuel cell stack consists of 300 hydrogen fuel cells in series. The parameters are shown in Table 1. The main material is stainless steel and heat insulator. The optimum operating temperature is 70 °C. For the cold start in a winter, the heat generated at the beginning is used to increase it temperature. Above 70 °C, heat is transferred to the heat load.

The heat load is mainly from the space heating which is related to the environment temperature. The local temperature is from in Bridgeport, CT.

Start-up time, especially in a high-temperature fuel cell system, forces one to set up scheduling only for day-ahead trading but not for spot trading.

The hydrogen production rate (moles/s) through the PEM electrolyzer can be calculated as:

$$m_{H2} = \frac{P}{2VF} \tag{14}$$

Where, P is the power (W), V is the voltage applied to a cell and it is 1.6 V in this simulation, and F is Faraday constant.

The power constraint on the electrolyzer is

$$PE_l < PE < PE_h \tag{15}$$

where, PE is power and PE_l and PE_h are the lower and upper input power limits. In addition, there is a hydrogen capacity constrain from the hydrogen tank.

Table 1 Parameters of a FC stack

Parameter	Value
Number of cells	300
Active area per cell	200 cm^2
Operating temperature	70 °C
Cathode pressure	2 atm
Anode pressure	2 atm

The area of the PV system is 200 m^2. The solar position, azimuth and altitude (in Fig. 6a), is based on the location in Bridgeport, CT and the maximum power output is 80 kW. Similar to a fuel cell stack, the power output from a PV system is also affected by the environment temperature as shown in Fig. 6b.

Results and Discussion

Figure 7 shows the environment and fuel cell stack temperatures and time "0" corresponds to 12 AM. The fuel cell stack only runs in the night. For the cold start, heat output lags the power. Heat supply is not available until the fuel cell stack temperature reaches 70 °C, the optimal operating temperature. Output heat will go to the local heat load and the rest will be stored in the heat tank. For the fuel cell stack, its efficiency is 33 % if it is only used to supply electricity. With the utilization of heat, it efficiency is close to 90 %.

In every day, spare power from the PV system can go to the electrolyzer to produce hydrogen as shown in Fig. 8. Here, the rated power of the electrolyzer is 20 kW. After sun sets, the fuel cell stack starts to run and the amount of hydrogen drops. In every day, the amount of hydrogen starts to increase from zero at 8 AM to 2600 moles at 5 PM. After that, the fuel cell stack starts to run and all hydrogen will be used up at 12 AM.

Figure 9 shows the profiles of the heat load and heat supply in the first 3 days. The heat load is mainly from the space heating which is related to the environment temperature. At the beginning of the first day, the fuel cell stack runs for 3 h and hydrogen is used up. In the day time, the amount

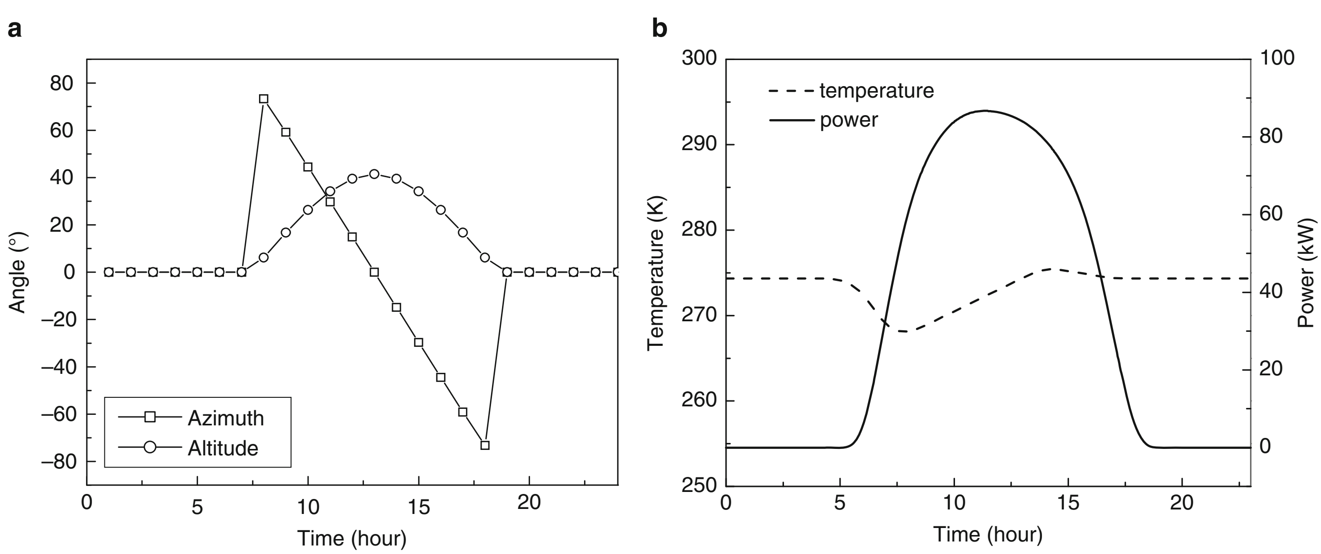


Fig. 6 Daily temperature profile and PV system output

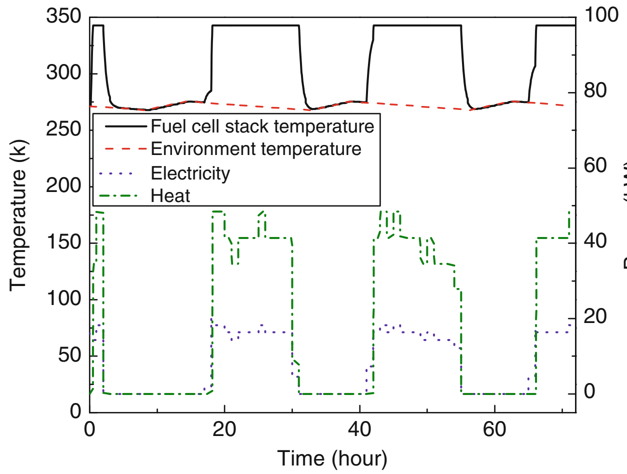


Fig. 7 Fuel cell stack temperature and electricity/heat supply

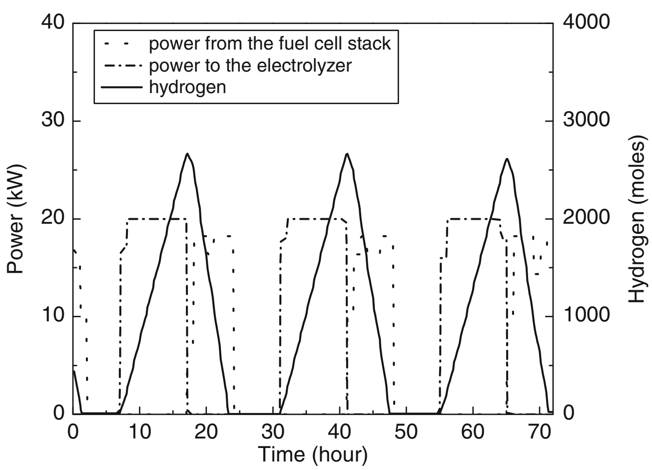


Fig. 8 The amount of hydrogen changes in the tank

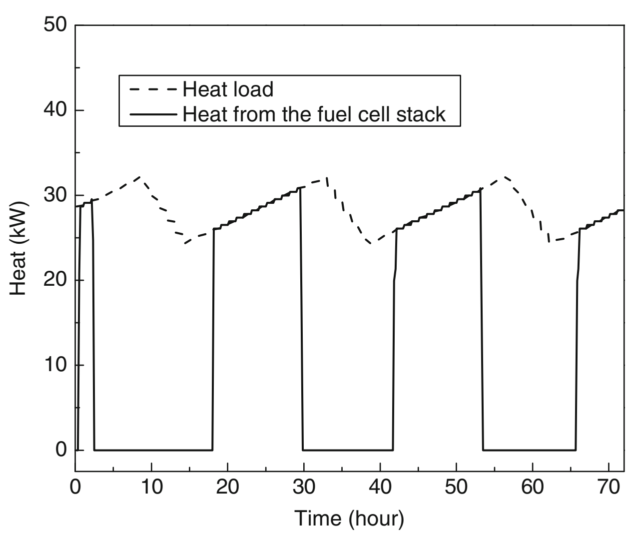


Fig. 9 The profiles of heat load and heat supply

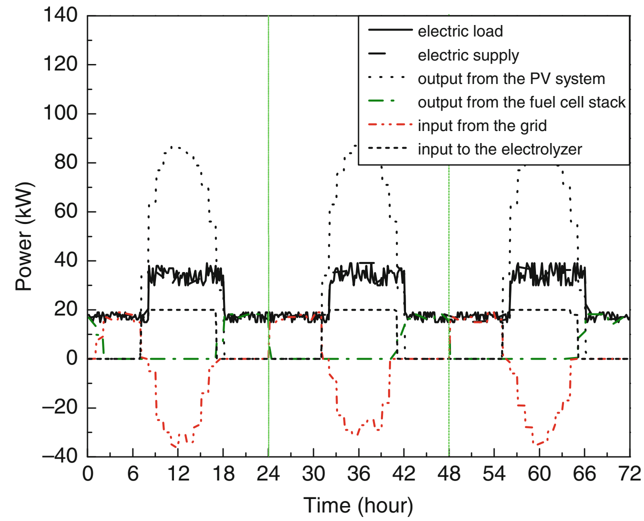


Fig. 10 The electricity profiles in the first 3 days

of hydrogen increases. Since this is electricity-led scenario and electricity from the PV system is enough for the local electric load and the electrolyzer, the fuel cell stack stops even there is hydrogen available. After sun sets, the fuel cell stack starts at 5 PM and heat is co-generated until hydrogen is used up again. From the second day, heat supply fluctuates periodically and 45.8 % of the heat demand can be met.

In Fig. 10, there is enough power available for the local electric load. At the beginning of the first day, power from the grid is needed since there is no enough hydrogen for the fuel cell stack to run. After sun rises, the electricity from the PV system with the maximum power around 85 kW is enough to supply the local electric load and to generate hydrogen as energy storage, the spare power flows to the grid with the maximum power 38 kW in Fig. 10. Therefore, the grid supplies 20 kW power to the system for 6 h just before the sun rises.

Figure 11 shows the performance indexes of the system. The price index increases from the 0.71 in the first day to 0.82 on the third day. While, the emission index drops from 0.82 to 0.80. This indicates that more electricity from grid is needed in from the second day and it is due to the initial hydrogen amount in the system. Moreover, both service quality and the overall performance index increase. Since the daily electric and heat loads are similar, more electricity and heat are provided from the second day.

Conclusions

A grid-tied microgrid with DEG, DES, and AD is simulated under an electricity-led scenario. Sufficient power is supplied to the local electric load from the PV system, the fuel cell stack, and the grid. The byproduct, heat, goes to the local

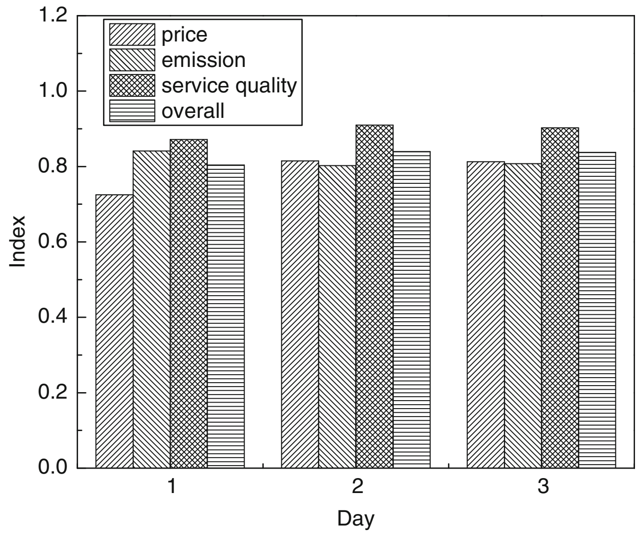


Fig. 11 The performance indexes in the first 3 days

heat load and 45.8 % heat demand can be met without other heat sources. As a CHP system, the efficiency of the fuel cell stack is close to 90 %. With the proposed performance indexes, the price, emission, service quality, and the overall index are between 0.8 and 0.9.

Future work includes the system optimization in the structure and the operation. Two other scenarios, heat-led and cost-led, will also be discussed. Eventually, the microgrid network will be studied.

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The SOC Estimation of a Lead Acid Rechargeable Battery

Linfeng Zhang and Xingguo Xiong

Abstract

A model of a lead-acid battery is presented with an equivalent circuit and the parameters are determined with experiments. An inductor is added into the circuit with the consideration from the output of impedance spectrum. Extended Kalman filter for the nonlinear system is used to estimate three state variables and further to calculate the state-of-charge. The algorithm is simplified and it can be implemented for the real-time estimation with an error less than 1 % in the testing with the SOC range between 60 % and 100 %. The testing is also conducted with a battery not fully charged and the estimation error is higher, close to 2 %.

Keywords

State-of-charge • Rechargeable battery • Extended Kalman filter

Introduction

Rechargeable batteries are widely used in portable devices, vehicles, and power grid. For electricity energy management, the accurate and real-time estimation of the state of charge (SOC) is necessary [1, 2] since it can not only protect battery from over-charging or over-discharging but also improve the battery utilization efficiency. In this paper, the SOC is defined as:

$$SOC = \frac{Capacity - \int idt}{Capacity} \tag{1}$$

Here, Capacity is the nominal capacity in Amper · hour (Ah), i is a discharging current, and t is discharging time. The SOC indicates the charges or energy left in a battery.

There are four simple ways to directly determine SOC: one is through the time integral of current. But the start point is required in the calculation and this point is hard to be obtained in most cases. In addition, the cumulative error is huge due to the measurement inaccuracy. The second one is through measurement of the electrolyte physical property due to the linear relationship between acid density and SOC. But, this method is only feasible with vented batteries [3]. The third one is through steady-state open circuit voltage since it is proportional to SOC. But there is no way to get this voltage in a dynamic system with insufficient rest period. The last one is from impedance measurement since there is a relationship between SOC and the phase angle. In a dynamic system, real-time measurement of phase angel is not accurate when the battery current is not zero [4, 5]. Therefore, SOC is better to be estimated and different algorithms or techniques have been developed according to the observation in a short time period or limited data points. In real application, the trade-off between the accuracy and the computing overhead should be considered especially in portable devices. Artificial neural network and fuzzy logic have been used in a wide SOC range with unknown initial SOC. Although the absolute error is less than 5 %, the implementation needs a powerful processor [6, 7]. Using Kalman filter or extended Kalman filter is another approach to estimate the SOC. This method is based on the models, equivalent

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_67,

circuits. Most of these circuits only consist of resistors and capacitors. With the assumption of the time derivative of the current as zero, the model is a linear system and the state variables can be observed. However, inductive part can be observed at frequency higher than 100 Hz through impedance measurement and it will affect the battery output when there is a sudden change in current [5]. In addition, most validation of the model is through the SOC comparison from estimation and a time integral of the current in discharging or charging separately.

In this paper, an inductor is added to a normal RC model of a lead-acid battery and the time derivative of the current is considered. The parameters in the model are determined through experiments and the effects of the inductor and the derivative of the current are considered in the extended Kalman filter. The battery is tested dynamically to check the accuracy of the SOC estimation through this model.

Battery Model

In a rechargeable lead-acid battery, there is a reversible chemical reaction when the battery is charged or discharged. Therefore, the energy can be converted from electricity to chemical energy, or vice versa. During battery discharging, reduction reaction occurs on the cathode and oxidation reaction on the anode.

$$PbO_2 + 4H^+ + SO_4^{2-} + 2e^- \rightarrow PbSO_4 + 2H_2O \text{ (cathode)} \tag{2}$$

$$Pb + SO_4^{2-} \rightarrow PbSO_4 + 2e^- \text{ (anode)} \tag{3}$$

Thus, the full-cell discharge reaction is

$$Pb + PbO_2 + 2H_2SO_4 \rightarrow 2PbSO_4 + 2H_2O \tag{4}$$

The solid product PbSO4 will stay on the electrode surface. The above chemical reaction rates are affected by SOC, charge/discharge rate, temperature, and age [8]. There are double charge layers on the anode and cathode surfaces where a positive (negative) ionic layer in the electrolyte is balanced by negative (positive) charges absorbed on the surface of the electrodes. These double layers can be considered as a plate capacitor with a series resistor in the equivalent circuit. The capacitance depends on the charge storage capacity of the battery and the resistance is between 0.1 mΩ to 20 mΩ [9]. During battery charging, the reaction directions reverse.

Figure 1 is the model of a rechargeable battery and it consists of two capacitors, three resistors and one inductor.

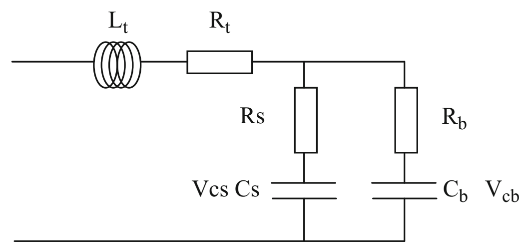

Fig. 1 The equivalent circuit of a battery

C_b is where the charges stored in the battery, C_s is for the double-charge layers and diffusion effect within the battery, L_t it is attributed to the electrode geometry and to the connections inside the cell, series resistance, R_t, is the internal resistance, which is related to the connections and electrolyte, R_s is the surface resistance, and R_b is the end resistance [5].

From the model, the following differential equations can be obtained:

$$\begin{bmatrix} \dot{V}_{cb} \\ \dot{V}_{cs} \end{bmatrix} = \begin{bmatrix} -\dfrac{1}{C_b(R_b+R_s)} & \dfrac{1}{C_b(R_b+R_s)} \\ \dfrac{1}{C_s(R_b+R_s)} & -\dfrac{1}{C_s(R_b+R_s)} \end{bmatrix} \begin{bmatrix} V_{cb} \\ V_{cs} \end{bmatrix} + \begin{bmatrix} \dfrac{R_s}{C_b(R_b+R_s)} \\ \dfrac{R_e}{C_b(R_b+R_s)} \end{bmatrix} I \tag{5}$$

$$V_0 = \begin{bmatrix} \dfrac{R_s}{R_b+R_s} & \dfrac{R_b}{R_b+R_s} \end{bmatrix} \begin{bmatrix} V_{cb} \\ V_{cs} \end{bmatrix} + \left[R_t + L_t s + \dfrac{R_b R_s}{R_b+R_s} \right] I \tag{6}$$

To have a linear system, V_0' is introduced and which is equal to the first term in the right hand side of Eq. (6).

The state-space equations in s domain from Eqs. (5) and V_0' are [10]:

$$\begin{bmatrix} \dot{V}_{cb} \\ \dot{V}_{cs} \\ \dot{V}_0' \end{bmatrix} = \begin{bmatrix} -\dfrac{1}{C_b(R_b+R_s)} & \dfrac{1}{C_b(R_b+R_s)} & 0 \\ \dfrac{1}{C_s(R_b+R_s)} & -\dfrac{1}{C_s(R_b+R_s)} & 0 \\ A(3,1) & 0 & A(3,3) \end{bmatrix} \begin{bmatrix} V_{cb} \\ V_{cs} \\ V_0' \end{bmatrix} + \begin{bmatrix} \dfrac{R_s}{C_b(R_b+R_s)} \\ \dfrac{R_e}{C_b(R_b+R_s)} \\ B(3,1) \end{bmatrix} I \tag{7}$$

$$A(3,1) = -\frac{R_s}{C_b(R_b+R_s)^2} + \frac{R_b}{C_s(R_b+R_s)^2} - \frac{R_s^2}{C_b(R_b+R_s)^2} + \frac{R_s}{C_s(R_b+R_s)^2} \tag{8}$$

$$A(3,3) = \frac{R_s}{C_b R_e (R_b+R_s)} - \frac{1}{C_s(R_b+R_s)} \tag{9}$$

$$B(3,1) = \frac{R_b^2}{C_b(R_b+R_s)^2} - \frac{R_s R_t}{C_b R_b (R_b+R_s)} + \frac{R_t}{C_s(R_b+R_s)} + \frac{R_s R_b}{C_s(R_b+R_s)^2} \tag{10}$$

V_{cb}, V_{cs}, and V_0' are state variables and B(3,1) is obtained with the assumption that the time derivative of the current is zero. The terminal voltage, V_0, is

$$V_0 = [0 \;\; 0 \;\; 1]\begin{bmatrix} V_{cb} \\ V_{cs} \\ V'_0 \end{bmatrix} + \left[R_t + Ls + \frac{R_b R_s}{R_b+R_s}\right] I \tag{11}$$

The inductance and the time derivative of the current are in the second term in Eq. (11). The observability verification is omitted here. In the measurement-update equations for the state variables, the state variables are corrected, Kalman filter with modified correction step is used.

$$\widehat{V}_k = \widehat{V}_{k-1} + K\left[y - \left(R_t + Ls + \frac{R_b R_s}{R_b+R_s}\right)I - [0 \;\; 0 \;\; 1]x\right] \tag{12}$$

Where, K is the Kalman filter gain.

Results and Discussion

The battery tested is a new sealed lead acid rechargeable (AGM, Power Patrol SLA1116) with a nominal voltage as 12 V and capacity, 18 Ah. The testing setup includes a LCZ meter (HP 4276A), a programmable DC electronic load (TEKPower 3711A), a programmable DC power supply (BK PRECISION 1788), and LabView programs developed for data acquisition and instrument control. All the experimental setup is in the Renewable Energy Research Lab at the University of Bridgeport. In order to measure the real capacity, the battery was fully charged first and given a 24-h rest. Then the battery was discharged at 18 A to 10.5 V in 2,306 s. Thus, the capacity at discharging current 18 A is 11.53 Ah. In addition, the state-estimation method is implemented as embedded Matlab Script with shift register to hold finite state variables in the previous time step. The battery is connected to the programmable DC power supply in charging and it is connected to the electronic load in discharging. In the battery dynamic testing, both electronic load and DC supply are connected to the battery and a designed current profile is followed to charge or discharge the battery. The experiments were done at room temperature 25 °C.

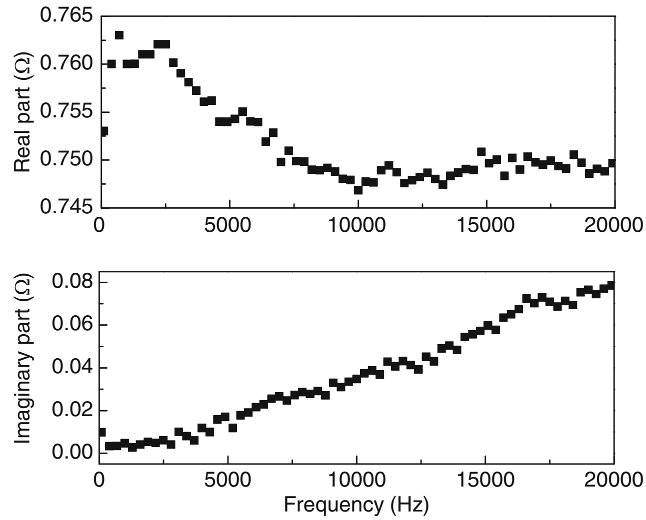

Fig. 2 The impedance spectrum between 100 Hz and 20 kHz

The parameters in the model are obtained from the battery nominal values and the experiments. C_b is obtained from the rated capacity 18 Ah with initial terminal voltage 12.6 V. Thus, C_b is 6,800 F (5,142 F). However, C_b is chosen as 10,000 F in the simulation after trial and error.

Furthermore, the impedance of the equivalent circuit from Fig. 1 is:

$$Z = j\omega L + R_t + \frac{\left(R_s + \frac{1}{j\omega C_s}\right)\left(R_b + \frac{1}{j\omega C_b}\right)}{R_s + \frac{1}{j\omega C_s} + R_b + \frac{1}{j\omega C_b}} \tag{13}$$

At high frequency, the effect of the capacitors can be neglected and latter the whole third term on the right hand side can be neglected too.

$$Z = j\omega L + R_t + \frac{R_s R_b}{R_s + R_b} \tag{14}$$

Therefore, impedance spectrum can be used to separate the fast and slow dynamics to determine the value of the parameters. Figure 2 is the impedance spectrums of the battery with SOC 100 %. In this testing, the impedance of the cable and connection is measured first and its effect on battery impedance can be removed. The imaginary part of Z increases linearly with frequency from 0 Ω to 0.08 Ω. Thus, the inductance is 0.636 μH.

To determine the internal resistance, a current-interrupt technology is used. Suppose a battery is providing a current. The Ohmic loss and the voltage across the capacitor cause

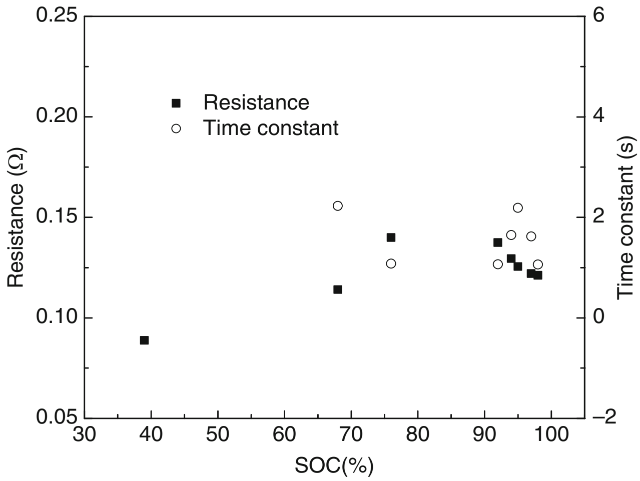

Fig. 3 Battery voltage in pulse discharging

Table 1 The parameters in the model

C_b	10,000(5,142)F
C_s	1,000 F
$R_b = R_s$	10 mΩ
R_t	0.1 Ω
L	30 μH

the terminal voltage drop. When the current is suddenly cut off, the Ohmic loss will immediately disperse while the voltage across the capacitor will take some time to increase. Therefore, the Ohmic loss or the internal impedance can be determined. Figure 3 shows the current pulse and the terminal voltage although the resolution of the electronic load is low. The average internal impedance in this battery is 0.125 Ω [11]. Considering the existence of the inductor, R_t is chosen as 0.1 Ω and R_b and R_s are the same as 10mΩ. The values of the parameters are listed in Table 1.

The battery is first tested in cyclic pulse charging and discharging at constant currents 1 A, 3 A, 4 A, and 18 A. Figure 4a and b show the voltage and current profiles in the pulse discharging. Here, the initial SOC is 100 %. During discharging, measured terminal voltage and estimated voltage gradually decrease. Figure 4c shows the voltages in the pulse charging. In both discharging and charging, the estimated terminal voltage is very close to the measured voltage when the battery is in the rest. But error exists when the current is not zero.

As we know, linear relation exists between the steady-state terminal voltage and the SOC but it is impossible for real-time SOC estimation through this voltage and the dynamic voltage is affected by the SOC, current, and temperature [12].

$$SOC = 0.595V_{ss} - 6.49 \tag{15}$$

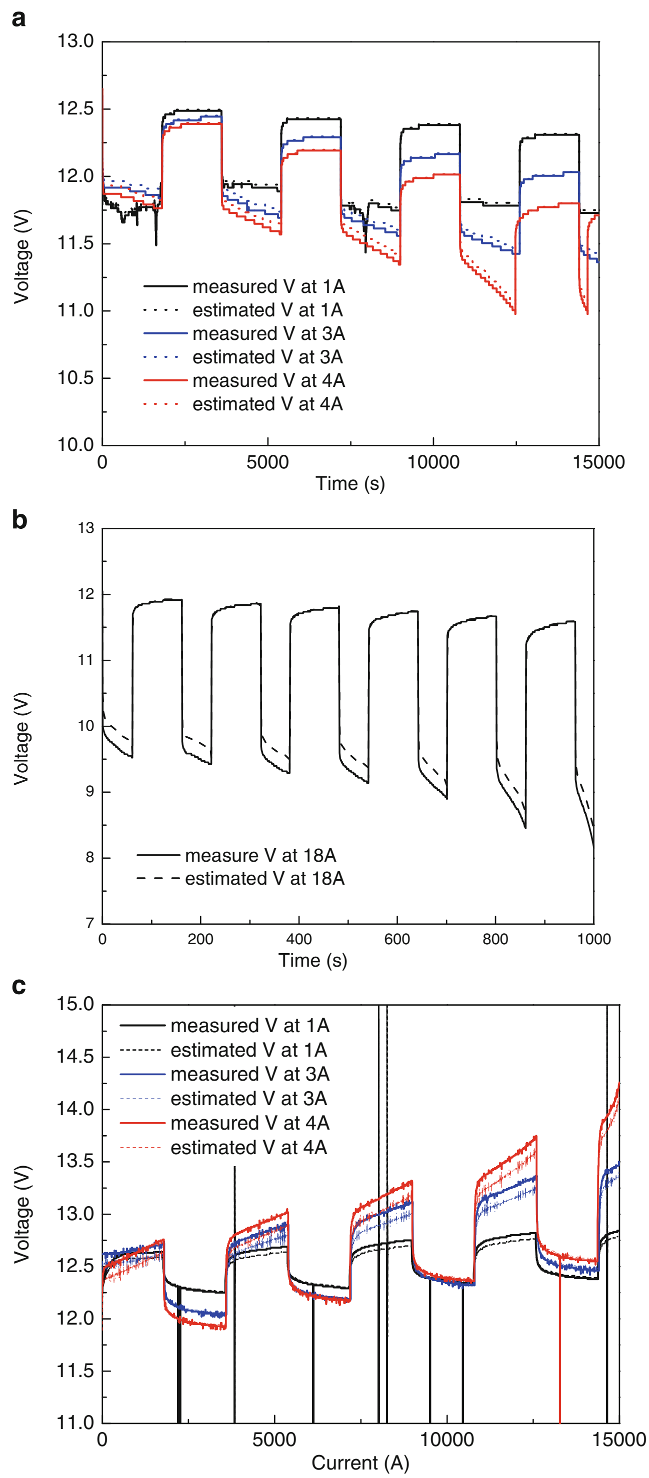

Fig. 4 The voltage profiles during the pulse discharging (**a**, **b**) and charging (**c**)

Figure 5 shows the V_{cb} at different SOC and there is also a linear relation between them. Therefore, the state variable V_{cb} can be used to determine SOC through a linear fitting.

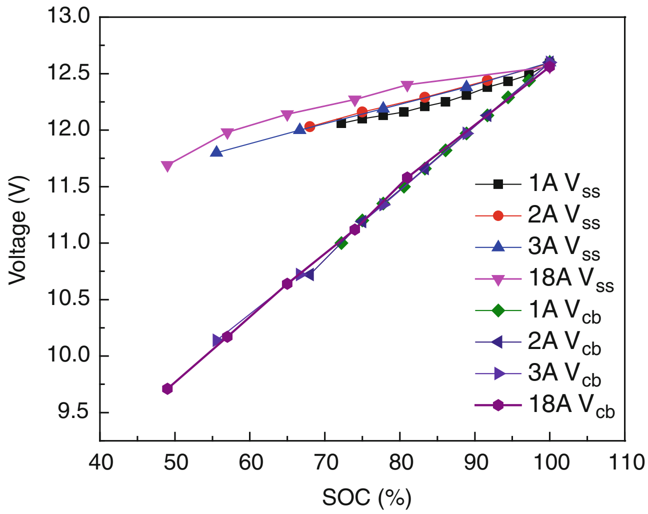

Fig. 5 The linear relations between the SOC and V_{ss}, and V_{cb}

$$SOC = -1.22 + 0.176V_{cb} \tag{16}$$

Equation (15) can be used to calculate the SOC based on the steady-state open-circuit voltage if there is an enough rest in the battery use. This SOC can also be used to verify the estimation. Equations (15) and (16) can be used to determine the initial values of the state variables especially when the estimation starts from the battery not fully charged.

In order to verify the accuracy of SOC estimation through the state variable, the battery is first fully charged. Then, the testing starts with a current profile shown in Fig. 6a. Here, battery is discharged at 18 A and charged at 5 A alternatively. In this graph, the estimated terminal voltage follows the measured voltage. The state variable, V_{cb}, is higher than the terminal voltage in discharging but lower than the terminal voltage in charging. This result is consistent with the model in Fig. 1. Figure 6b shows the corresponding SOC obtained from the time integral of current and Eq. (16). The absolute error is less than 0.3 % and this error is related to the resolution of the voltage meter.

To expand the SOC range and have a rest for the battery, a test is done with the current profile shown in Fig. 7a. Here, the battery is first discharged at 8 A, 16 A, 24 A. After 30 min rest, the battery is discharged at 18 A seven times. There are two estimated terminal voltages: one is obtained from a fully charged battery and the other one is from a battery with SOC as 71 %. Figure 7b shows the corresponding SOC obtained from the time integral of current and the estimation. The absolute error is less than 1 % in the first estimation and it is less than 2 % in the second one. The big error in the second one is due to the linear fitting in

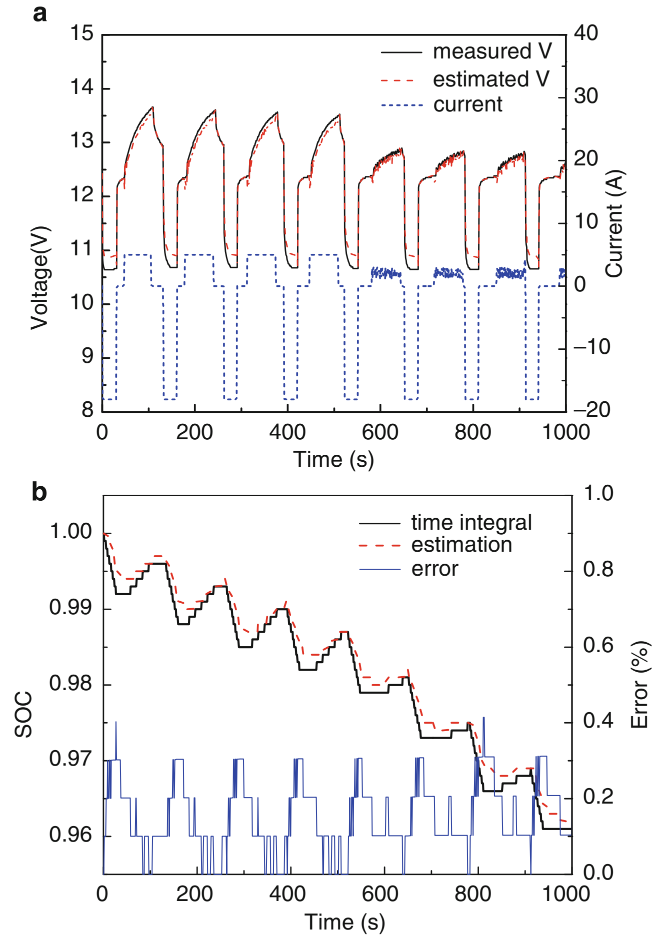

Fig. 6 Measured and estimated voltages in a battery dynamically charged and discharged (**a**) and the comparison of SOCs from the time integral of current and V_{cb} (**b**)

Eq. (15) in addition to the fitting in Eq. (16) and the measurement accuracy. In the real application, such as an electric vehicle, the open circuit voltage at steady state can be used to verify the estimation and determine the initial value of the state variables.

Conclusions

The model of a lead-acid battery is simplified as an equivalent circuit including a series resistor, inductor, and parallel capacitors. The parameters in this model are obtained through the nominal capacity, Impedance spectrum, and voltage-divider method. The experimental results show that the error of the SOC estimation is less than 1 % if the estimation starts from a fully charged battery and it is less than 2 % if it starts from a battery with SOC less than 100 %. This model can be extended to other types of rechargeable batteries.

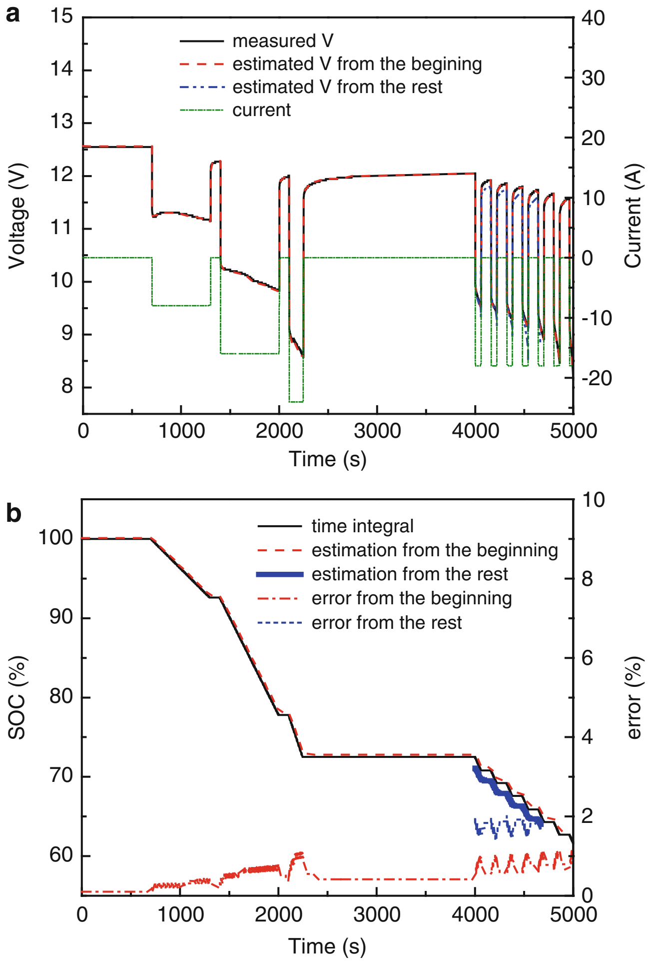

Fig. 7 Measured and estimated voltages in a battery dynamically discharged (**a**) and the comparison of SOCs from the time integral of current and V_{cb}(**b**)

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Fast Computation of Frobenius Map Iterates in Optimal Extension Fields

Walid Mahmoud

Abstract

The *j-th* iterate of Frobenius map is required in computing field multiplication and inversion that are necessary for code-theoretic and cryptographic applications in elliptic curve cryptography. In this paper, we propose a fast method for computing Frobenius map operation in optimal extension fields $GF\,(p^m)$ using polynomial basis representation for the field elements. In comparison with other existing approaches in the literature, our approach is associated with infinitesimal execution time in exchange for slight increase in space requirements.

Keywords

Frobenius map • Optimal extension fields $GF\ (p^m)$ • Polynomial basis representation • Elliptic curve cryptography • Finite field inversion

Introduction

TYPE II optimal extension fields (OEFs) are type of finite extension fields $GF\ (p^m)$ with characteristic p being a prime number and irreducible polynomial $f\,(x) = x^m - \omega$, a binomial, where $\omega = 2$. Such fields simplify arithmetics in the extension field $GF\ (p^m)$ itself and its associated subfield $GF(p)$ [1, 2].

In finite extension fields the Frobenius map is necessary in computing field multiplication and inversion. The *j-th* iterate of Frobenius map is the operation of computing the *j-th* power of a nonzero element $\alpha \in GF\ (p^m)$ when raised to the characteristic p, i.e., α^{pj}, which is a map to other element in the same extension field [3, 4].

Given a nonzero field element $\alpha \in GF\ (p^m)$, it can be represented using polynomial basis representation (PB) as $\alpha = \sum_{i=0}^{m-1} x^i$, and its *j-th* iterate of Frobenius map is given by

$$a^{p^j} = \sum_{i=0}^{m-1} a_i x^{i_p j} = a_0 + a_1 x^{p^j} + \ldots + a_{m-1} x(m-1)^{p^j}. \quad (1)$$

The authors in [5] calculated the *j-th* iterate of Frobenius map using $M \times M$ matrix, with complexity of m^2 subfield multiplications in the subfield $GF\ (p)$.

The authors in [6] reduced the computation of the powers in x, on the right-hand side in (1), such that

$$x^e \equiv \omega^q x^s \mod f(x), \quad (2)$$

to further reduce the complexity to be $(m-1)$ subfield multiplications in the subfield $GF\ (p)$.

The authors in [7] took advantage of normal basis representation (NB) in accelerating the computation of the iterates of Frobenius maps. Using such a basis, the iterates are simply cyclic-shifts associated with almost free execution time. However, NB not the desirable basis because of the requirements for basis conversions and the very expensive execution time associated with NB multiplication.

In this paper, we continue working on what was done by other authors and propose a method for fast computation of Frobenius map operation. We make use of the properties of type II OEFs to further accelerate the computation of the iterates of Frobenius map using a lookup table, and to reduce the required number of subfield multiplications to a constant value. In comparison with other similar approaches existing

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_68,

in the literature, our approach is associated with less execution time in exchange for slight increase in space requirements.

This paper is organized as follows. In section “Existing Approaches”, we provide more details on other existing approaches. In section “Proposed Approach”, we present and explain our proposed approach. Finally, the conclusion is drawn in section “Closing Remarks”.

Existing Approaches

The Frobenius map is a special automorphism of commutative rings with prime characteristic p, an important class which includes finite fields and their extensions, where it maps every element to its p-*th* power [8]. In particular, given $GF(p^m)$ such that $p = 2^k - c$ with $\left\lfloor \frac{k}{2} \right\rfloor \geq \log_2(c)$, a pseudo-Mersenne prime, and the irreducible polynomial $f(x) = x^m - \omega$, an irreducible binomial with $\omega = 2$, then $GF(p^m)$ is defined as Type-II OEF [9]. In such a case, when a nonzero element $\alpha \in GF(p^m)$ is represented with polynomial basis representation (PB), then the j-*th* iterate of Frobenius map for α is exactly as given in (1).

In [5], the j-*th* iterate of Frobenius map is calculated using $M \times M$ matrix, with complexity of m^2 subfield multiplications in the subfield $GF(p)$. Given that $\alpha \in GF(p^m)$ represented using PB as $\alpha = \sum_{i=0}^{m-1} a_i x^i$ the authors viewed the j-*th* iterate of Frobenius map as exponentiation problem of $GF(p)$-linear mappings. The matrix that describes the mappings is constructed by considering the PB of $\left(x^{ip^j}\right)$ terms for $i = 0, 1, \ldots, m - 1$ as follows

$$\left(x^{ip^j}\right) \equiv s_{0,i}^{(j)} + s_{1,i}^{(j)} x + \ldots + s_{m-1,j}^{(j)} x^{m-1}, \tag{3}$$

along with making use of the identity $f(x) = 0$, whereby the basis element x is a root of the irreducible polynomial $f(x)$.

In [6], the authors accelerated the Frobenius map operation further in using PB representation for the field elements. Given that $\alpha = \sum_{i=0}^{m-1} a_x x^i$ using PB, the authors expressed the j-*th* iterate of the Frobenius map for a nonzero element $\alpha \in GF(p^m)$ as follows

$$a^{p^j} \equiv a_{m-1} x(m-1)^{p^j} + \ldots + a_1 x^{p^j} + a_0 \mod f(x), \tag{4}$$

for a positive integer j representing the desired iterate and $(0 \leq i \leq m - 1)$, where the field irreducible binomial $f(x) = x^m - \omega$ is defined over the subfield $GF(p)$ with ω a subfield element. Then, they have focused on the elements that are not kept fixed, like $\left(x^{ip^j}\right)$ terms in (4) for $(1 \leq i \leq m - 1)$. By utilizing the special properties of the field irreducible binomial $f(x)$, the authors in [6] expressed the terms affected by the j-*th* iterate of the Frobenius map as follows

$$x^e \equiv \omega^q x^s \mod f(x), \tag{5}$$

whereby $s \equiv e \pmod m$, $q = \frac{e-s}{m}$ and exponent $e = ip^j$. Based on Corollary 2 in their paper, they further reduced the expression to

$$x^e \equiv \omega^q x^i \mod f(x). \tag{6}$$

From above discussion, the cost of the j-*th* iterate of Frobenius map is exactly $(m - 1)$ subfield multiplications, in the subfield $GF(p)$, that still require subfield modular reductions, given that the terms $\omega^q x^i$ are previously computed for all $(1 \leq i \leq m - 1)$.

The advantage of using normal basis representation (NB) for computing Frobenius map operation in $GF(p^m)$ is utilized in [7]. For example, given a nonzero element $\alpha \in GF(p^m)$ represented using NB and its equivalent vector representation as follows

$$\alpha = \sum_{i=0}^{m-1} a_i x^{p^i} = (a_0 a_1 \ldots a_{m-3} a_{m-2} a_{m-1}) \tag{7}$$

then, its 1-*th* Frobenius map is given by

$$\begin{aligned} \alpha^p &= \left(\sum_{i=0}^{m-1} a_i x^{p^i}\right)^p = \sum_{i=0}^{m-1} a_i x^{p^{i+1}} \\ &= (a_{m-1} a_0 a_1 \ldots a_{m-3} a_{m-2}). \end{aligned} \tag{8}$$

Comparing (7) and (8) above, it is apparent that in using NB the j-*th* iterate of Frobenius map is simply reduced to either j-*th* right cyclic-shifts in software, or j-*th* permutations in hardware (no dedicated hardware is required). Therefore, the j-*th* iterate of Frobenius map is a free execution time operation in using NB for the field elements of the concerned extension field. Given the above, however, in practice NB is not as common as PB, NB multiplication is associated with much higher execution time in comparison with PB multiplication, in addition to the requirement for basis conversions to NB at the very first computation and to PB at final computation. Therefore, the focus here is on accelerating Frobenius map using PB representation.

Proposed Approach

Given a nonzero element $\alpha \in GF(p^m)$ represented as $\alpha = \sum_{i=0}^{m-1} a_x x^i$ using PB, its j-*th* iterate of the Frobenius map is given by

$$a^{p^j} = \sum_{i=0}^{m-1} a_i x^{ip^j} = a_0 + a_i x^{p^j} + \ldots + a_{m-1} x^{(m-1)p^j} \mod f(x). \tag{9}$$

In using Type-II OEFs, the field irreducible binomial $f(x) = x^m - \omega : \omega = 2$. Given that the basis element x is a root of $f(x)$, then we have

$$\omega \equiv x^m \mod f(x), \tag{10}$$

or equivalently $\omega = x^m$. As given in [6], if the extension degree m is square-free value, then we have

$$p \equiv 1 \mod m. \tag{11}$$

Based on (11) above, we can express the terms affected by the action of the Frobenius map as follows

$$x^{ip^j} = x^{\left\lfloor \frac{ip^j}{m} \right\rfloor m} x^{ip^j \mod m} = x^{\left\lfloor \frac{ip^j}{m} \right\rfloor m} x^i = \omega^{q_i^j} x^i, \tag{12}$$

for $q_i^j = \left\lfloor \frac{ip^j}{m} \right\rfloor$, a *j-th* iterate of Frobenius map and $(1 \le i \le m-1)$. This is because $x^m = \omega$ using (10) above, and $ip^j \mod m = i$ using (11) above. From (12) above, the *j-th* iterate of the Frobenius map is thus given by

$$a^{p^j} = \sum_{i=0}^{m-1} \left(a_i \omega^{q_i^j} \right) x^i \mod f(x) \; \forall (0 \le i \le m-1). \tag{13}$$

Given that $\omega = 2$ in using Type-II OEFs, with the fact that the exponent (q_i^j) in (13) above is simply a positive integer, then we have

$$a^{p^j} = \sum_{i=0}^{m-1} (a_i 2^k) x^i \mod f(x) \; \forall (0 \le i \le m-1), \;\; k - q_i^j. \tag{14}$$

The $(m-1)$ subfield multiplications of $(a_i 2^k)$ terms given in (14) above can be reduced to shifts based on the value of k. This is the result of multiplying the subfield coefficients a_i for $(1 \le i \le m-1)$ by a power of 2 value, i.e., 2^k, depending on the value of the positive integer k. However, such shifts still require subfield modular reductions as given in [5, 6].

To further improve the calculation of $(a_i 2^k \mod p)$ expression for $(1 \le i \le m-1)$, i.e., the subfield multiplication and modular reduction operations for some characteristic $p \ge 5$ of $GF(p^m)$, we have noticed that the output of such expression is a cyclic-sequence of values taken from the subfield $GF(p)$. Assume that we have $GF(5^m)$, thus $p = 5$ and the subfield elements have coefficients $a_i \in GF(5) = \{0, 1, 2, 3, 4\}$ for $(0 \le i \le m-1)$. With the fact that k is merely a positive integer, then our approach can be described as follows:

Given $a_i = 0$ for $(0 \le i \le m-1)$, *the coefficients whose value is equal to zero*, the result of calculating $(a_i 2^k \mod p)$ expression is equal to zero regardless of the value of k and the characteristic p.

Given $a_i = 1$ for $(0 \le i \le m-1)$, *the coefficients whose value is equal to one*, the result of calculating $(a_i 2^k \mod p)$ expression is given as follows: For $k = 1, 2, 3, \ldots$, we have

$$\begin{aligned}\left(a_i 2^k \mathrm{mod} p\right) &= (p-3), (p-1), (p-2), (p-4), (p-3), \ldots \\ &= 2, 4, 3, 1, 2, 4, 3, 1, \ldots : p = 5.\end{aligned} \tag{15}$$

The cyclic-sequence in (15) is considered as the reference for deriving the cyclic-sequences of other coefficient values. Notice how the first element in the sequence is equal to 2. This element comes right after the one that has value equal to 1, keeping in mind, 1 is the value of the coefficients currently under consideration.

Again, using the sequence in (15), we can find the cyclic-sequence for $a_i = 2$ for $(0 \le i \le m-1)$, i.e., *the coefficients whose value is equal to two*. The new cyclic-sequence starts with the element having the value 4 and continues with the following elements in the reference sequence in their respective order. This element comes right after the one that has value equal to 2, keeping in mind, 2 is the value of the coefficients currently under consideration. Thus, our new cyclic-sequence for $a_i = 2$ is given by

$$\left(a_i 2^k \mathrm{mod} p\right) = 4, 3, 1, 2, 4, 3, 1, 2 \ldots : \; p = 5. \tag{16}$$

By following this way, the cyclic-sequences can be derived for the remaining coefficient values, i.e., $a_i = \{3, 4\} \in GF(5)$ for $(0 \le i \le m-1)$. Table 1 presents the obtained cyclic-sequences.

From Table 1 above, note that for all coefficients $a_i \in GF(p)$ when k is zero the result of computing $(a_i 2^k \mod p)$ is the coefficient itself. In addition, k value can be easily obtained using the following expression

$$k = q_i^j = \left\lfloor \frac{ip^j}{m} \right\rfloor (\mathrm{mod} p - 1). \tag{17}$$

Based on (17), k value is independent of the field element in which its *j-th* iterate of Frobenius map is required and depends on the coefficient location i with values never exceed $(p-1)$. Note that m and p are fixed in the given $GF(p^m)$ and j is known a priori. The values of k can calculated off-line and can be used in conjunction with

Table 1 Cyclic-sequences for ($a_i\, 2^k$ mod 5)

	$a_i \in$ GF(5)				
2^k	0	1	2	3	4
2^1	0	2	4	1	3
2^2	0	4	3	2	1
2^3	0	3	1	4	2
2^4	0	1	2	3	4
2^5	0	2	4	1	3
.	.	.	.	.	.

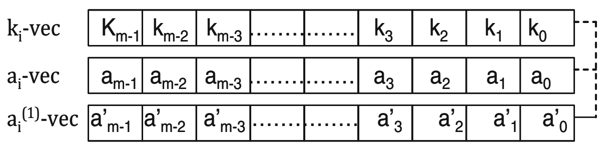

Fig. 1 Computing α^p using k_i-vec and Table 1

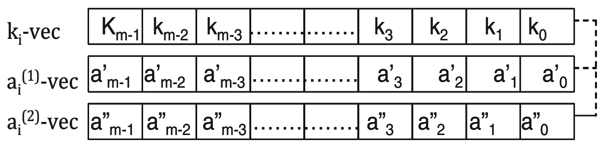

Fig. 2 Computing α^{p2} using k_i-vec and Table 1

Table 1 to instantly map the result of ($a_i 2^k$ mod p) computation for any coefficient $a_i \in GF\ (p)$.

Let us consider an example to show how (17) and Table 1 are used to accelerate Frobenius map computation. Given a nonzero element $a^i \in GF\ (5^m)$ in which its *j-th* iterate of Frobenius map is required, and $\alpha = \sum_{i=0}^{m-1} a_i x_i$ with vector representation denoted as a_i-vec $= (a_{m-1}\, a_{m-2} \ldots a_2\, a_1\, a_0)$. Referring to (17) and assuming $j = 1$, then we have k_i-vec$=\left\lfloor \frac{ip}{m} \right\rfloor$ (mod $p - 1$) for $(0 \leq i \leq m - 1)$, the vector of precomputed k values for each coefficient location. k_i-vec $= (k_{m-1}\ k_{m-2}\ \ldots\ k_2\ k_1\ k_0)$ can be computed off-line, with values $k_i \in \{0, 1,\ldots, p - 1\}$ for $(0 \leq i \leq m - 1)$.

Using Table 1, we can change a_i-vec according to k_i -vec to have $a_i^{(1)}$-vec that is equivalent to α^p as shown in Fig. 1. Note that a_i-vec specifies the columns, k_i -vec specifies the rows and $a_i^{(1)}$-vec specifies the mapping results in Table 1 that correspond to the location of each coefficient. Given that k_i-vec is kept unchanged and the elements of $a_i^{(1)}$-vec are again changed according to *ki* -vec using Table 1, then the result is $a_i^{(2)}$-vec that is equivalent to a^{p^2} as shown in Fig. 2. Therefore, if we repeat this process *j*-times, then the result is $a_i^{(j)}$-vec that is equivalent to a^{p^j}, the *j-th* iterate of Frobenius map since $a^{p^j} = \overbrace{\left((a^p)^p)^p \ldots\right)^p}^{j-times}$.

Given that k_i-vec is computed off-line, all the required processing to compute the *j-th* iterate of Frobenius map for $\alpha \in GF\ (5^m)$, is accessing Table 1 to change a_i-vec *j*-times according to k_i-vec.

comparison with other approaches, our approach does not require $(m - 1)$ subfield multiplications and their corresponding modular reductions. Using our approach, we only need m memory locations to store k_i-vec. Also, we need $(p - 1) \times (p - 2) = p^2 - 3p + 2$ memory locations for the lookup table, in addition a routine to access the table at runtime. Given the advancements in computer processing speeds and storage capacities, these requirements seem reasonable.

For example, assume that the requirement is to compute the 7-*th* iterate of the Frobenius map of element $\alpha \in GF\ (5^{32})$. Then, we have $j = 7$, $p = 5$ and $m = 32$. Thus, using our approach we need 32 memory locations to store very small integer values for k_i-vec, 12 memory locations to store very small integer values for the lookup table and 7 accesses to the lookup table.

Based on above discussion, our approach that is based on cyclic-sequences is associated with almost free execution time in exchange for slight increase in space requirements in computing the *j-th* iterate of Frobenius map. Note that our approach can be easily extended to higher characteristic extension fields $GF\ (p^m)$. To achieve this, all we need to do is to generate the lookup table and k_i-vec off-line for the optimal extension field $GF\ (p^m)$ of interest.

Closing Remarks

In this paper, we proposed a very fast method to compute the *j-th* iterate of Frobenius map, or equivalently the p^j-*th* power operation, in optimal extension fields $GF\ (p^m)$ using polynomial basis representation for the field elements. Such a map is required in computing field multiplication and inversion that are necessary for code-theoretic and cryptographic applications in elliptic curve cryptography. The conducted analysis confirmed that our approach is associated with infinitesimal execution time in exchange for slight increase in space requirements in comparison with other similar approaches available in the literature.

Acknowledgment The author would like to warmly thank peer reviewers for their help in reviewing this manuscript.

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Product Owner Responsibilities in the Project Assurance Process: Bridging Uncertainties Gaps

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Abstract

The product owner role in software engineering by the agile principle is a key one. He has many traditional responsibilities such as initiating a project, defining and accepting functionality and the entire product. At the same time his other responsibilities remain hidden or undefined in many projects. Unfortunately that is exactly the reason of failure for many projects and therefore here we debate and review his responsibilities and duties in other project elements and stages in order to show how important his input is to the project and other team members activities, primarily project verification and validation activities. The product owner's contribution to the team domain knowledge, prototyping, tests planning and project backlog is crucial and cannot be omitted in companies desiring success through meeting actual customers' expectations.

Keywords

Software engineering • Software quality • Product owner

Introduction

Several different approaches can be applied to the software engineering process depending on the project nature, goals and environment. It can be based on the traditional plan-driven (waterfall) model [1] or agile development methodologies such as SCRUM [2], Extreme Programming (XP) [3] and so forth. The agile methodologies have clear advantages in developing the business oriented applications due cost saving, increased flexibility of defining the requirements and faster development cycle [4]. Software engineering is focused on the constant communication, valuing working software over process objectives or excessive design. However, it can be discussed [5] that the agile development principles, which are simple in theory, are difficult to apply in any organization without adjustments in the organization or team members approaches and working habits. Besides, even applying the most advance software engineering methodologies does not guarantee the success of the project. Customer satisfaction reviews show that the gap between delivered and expected software is sufficient—up to 27 % of all projects fail because of that gap [6]. Besides, only 20 % of functionality in average is reported to be used "often" or "always" [7]. Therefore the process of quality assurance and the correct application of the software engineering cycle become very important. It is nearly impossible without involvement of the key person of any product—the product owner. His responsibilities are well-defined for the initiating and finalizing stages of the project, but remain under-discussed and hidden within the scope of internal software engineering stages. As testing is one of the most costly parts of the software process [8], the involvement of the product owners in the testing activities involved with agile development are an interesting field of the research. The absence of product owner involvement can corrupt or destroy the testing and development process. That is why it is so important to list and debate his responsibilities in order to give enough guidance on how product owner

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_69,

involvement should be arranged and synchronized with other key project activities to improve the overall result.

The paper is organized as follows: section "Product Owner" presents the product owner concept, and section "Quality Assurance Process" is dedicated to revising some basics of the project assurance process. Section "Product Owner Responsibilities from the Quality Assurance Perspective" presents the author's view on additional product owner responsibilities of importance by areas. Section "Conclusions" summarizes the paper with conclusions.

Product Owner

The product owner is the person who is responsible for the product development. He owns the product, defines which features goes into the production, specifies them and accepts both features and the product release.

The product owner tightly cooperates with other team members during the product development, assisting them in building the right product. At the same time, the product owner has many other duties and therefore may be unable to be of service to the team every minute. Therefore it is very important to clearly define his duties in order to organize a transparent process for all involved parties. The product owner's commitment into the product backlog and defining the scope of the project and features is well described and do not need any more clarification other than internal organizational procedures. Below we would like to debate the product owner responsibility in other project stages including mainly the quality assurance process.

Quality Assurance Process

The quality assurance process contains many different kinds of quality inspection activities, which are designed to identify specific problems in the build software and so provide the information to both development and management team regarding the status of the product health and readiness to be released. Quality assurance starts with development because the developers are also members of the quality assurance initiative (it does not solely belong to the testers).

The quality assurance process can be divided into verification and validation. Verification is testing the product, i.e. verifying that it acts correctly, while validation is ensuring that the product implements features accordingly to customer/product owner vision of the product.

Testing includes unit testing, integration testing, functional testing, performance testing, acceptance testing, installation testing, user experience/usability testing and some other very specific kinds of testing. Unit testing is used to verify correctness of work of each individual block and is normally carried on by the development team either manually or mostly automated including usage of the test driven development methodology. Integration testing is used to verify correctness of block interfaces, i.e. its ability to cooperate with other blocks of the build software accordingly to the architecture and design documentation. This is also mostly very technical process and is organized by the development and technical testing team. The next stage of testing is called system testing because testing is lifted from individual block level to the system level, i.e. during those testing the system is tested as a whole rather that an individual pieces. It includes functional testing, performance testing, acceptance testing, usability testing and installation testing. The product owner will decide to release or postpone the product based on the developed features, testing results and the external environment.

Product Owner Responsibilities from the Quality Assurance Perspective

In the quality assurance process it is not easy to identify the responsible person and therefore different companies define different roles to manage it. Some companies recognize testers to be in charge of quality assurance, while others see the research and development manager be the driving force. The role of the product owner in managing quality assurance process has not been recognized as important so far. He has been seen as either a provider for input such as verification requirements or merely another resource to carry on certain tests.

Domain Knowledge

The product owner's main property is the knowledge in the product domain area. He represents this knowledge in the team and collaboration with the customers. The usage of the product owner domain knowledge is very limited in many organizations and has degenerated to

– Defining functional request and associated business value (usage cases);
– Accepting the developed functionality during the demo meeting and final product acceptance.

At the same time the product owner domain knowledge responsibility should be much wider and include responsibilities such as:

– Spreading the domain knowledge among the team. It is clear that the quality of the team members' work without proper domain knowledge is much lower. At the same time they are not domain experts and are unable to upgrade themselves or follow the domain news.

Therefore it becomes crucial for the product owner to organise educational course both for beginners and for periodic updates transferring processed domain news to team members in much simpler terms;

– Ensuring that the business cases are turned into correct test cases and those are not artificial, but cover actual business needs. This can be done in form of periodic test team reviews and allows product owner to save time spending it on test reviews instead of trying to ensure personally the correct functionality work constantly validating it manually.

Prototyping

Continuing what has been previously said regarding test cases, the prototyping question should be raised. Prototyping is the efficient method to discover any feature description problems and incorrect or missing statements while leveraging the expectations of the end-user against actually developed functionality.

The prototyping can be organized in different forms

– Paper based prototyping: it is mostly used designing user interfaces, simulating the user interaction with the software or visualize key attributes or characters in the game development;
– Software emulation: here we concentrate on the functionality available to the end-user sufficiently simplifying or skipping the inner logic;
– Virtual prototyping: the focus group is used here, which is locked in one room for some time discussing the what-if scenarios of features behavioural, characteristically and other attributes following the domain experts advices. A thinking-aloud is a good example of such sessions [11];

In all three types of prototyping the product owner involvement is important to the following aspects:

– *Decide on execution of the prototyping process*: the prototyping process is not entirely free of charge and therefore it is important to use it only if necessary and this is the task of the product owner to assess the project features and attributes, select those, which lack certainty and decide to prototype them in form on one or several sessions;
– *Organize the prototyping session*. The prototyping session should be organised in form on time, place and participants;
– *Define level of prototyping and required functionality* to be available by the session. As it is described above there are several prototyping forms, and so the product owner needs to decide on how to prototype and what do we need before it can be completed: only pen, paper and a set of guidelines or a simulating (working) software;
– *Lead the prototyping process*: The prototyping session involving a set of members requires both leading and observing to be able to record the session results;
– *Participate in the prototyping as a domain expert*. The product owner is one, but of course not the only domain expert in the prototyping session.
– *Analyse the prototyping results and decide on project corrections*

Project Backlog

The product backlog is owned, supervised and filled by the product owner. The project backlog is a jointly owned by the scrum master (project manager), test team and product owners. Unlike the product backlog, the project owner has no such power over project backlog and has to cooperate with other team members submitting the information. At the same time the project backlog is not completely unrelated to the product owner as some agile development authors suggest. The following are key activities of the product owner related to the project backlog:

– Prioritising features
– Prioritising error reports
– Revising estimates and making decisions to skip
– Leading the features development basing on their current status

Knowledge Base

An important source of the information for the team including planning and executing tests is a knowledge base that may exist in the organization. In the past the iterative and waterfall method functional specifications were serving as the knowledge base and providing a good enough level of information and current status of the product. Although, the elimination of those with agile practices made the reaction of the team on changes much more rapid, the review of the past decisions become hard or impossible. Mostly this information is communicated during the daily meetings, but short memory span of people already stressed by the volume of tasks and other external environmental factors affects the availability of such information to others. The testing team is the most affected by this, having been at the end of the communication and changes chain. They are faced with a lack of knowledge that leads to unawareness of actual functionality and rules that should be tested, as well as incomplete test coverage. This produces a massive negative customer feedback regarding the non-working software.

The product owner contribution to this knowledge base in the changing in the agile methodologies is proving to be crucial. As the domain expert he is able to commit into the knowledge base the latest knowledge about decisions using the most correct terminology to describe said decisions. This information is the initial source for the developers, and is vital to the tester during back communication regarding discovered defects and in ranking primary sources for test cases creation and users' education. The subsequent knowledge base review and comparison to existing tests gives an overview of the manual or automated test coverage of the product.

Tests Planning

In planning the testing of features, the test team picks up the business cases stated along every feature existing in the project backlog and turns these into tests. They follow additional information they can obtain from the knowledge base and the iteration initiation meeting. After they complete describing the test cases, they are often uncertain about test cases' alignment to actual needs and expectations but prefer to ignore this, moving forward to the testing stage been unable to fix it themselves. This is an important mistake that many teams make, producing generally unreliable test content. Therefore it is important to organize a short meeting with the product owner specifying what is to be tested and how it is going to be tested. This is the only way to ensure correctness of the testing phase, closing all gaps produced during development.

The other kind of test planning which is impossible without product owner input is the performance tests one. It is the product owner's responsibility to define the customer profiles, cluster them into groups and present them to the test team to turn into performance testing scenarios. The product owner is not expected to define all the information along with the profiles without the cooperation with the technical person. In most cases such a technical person is the software architect, since not only are tests derived from customer profile clusters, but also from the system design and attributes. It is also important to monitor the current product position and check the direction it slowly migrates in. It can happen, that, after some time, the earlier defined performance tests do not correspond any longer to actual customer profile and the only person who is able to spot that and initiate changes is the product owner.

The usability testing is also impossible without product owner commitment. Generally speaking, usability evaluation helps to determine whether interactive systems support users in their everyday work tasks. However, knowledge about those tasks and about the work-domain is difficult to bring to bear on the processes and outcome of usability evaluation. One way to include such work-domain knowledge might be the cooperative usability testing [9]. The simplest usability testing is similar in many organizational aspects to prototyping and mostly includes observing users activities during the session. The most complex usability test methodologies involve domain expert cooperation along the usage of the delivered software and discussion on the results. This allows testing to get access to the users reflections much earlier and much deeper than simply observing or watching video recordings. It also involves thinking aloud [11], leading the test, pushing through the local usability gaps and verbalization of problems. The analysis of the usability issues includes quantitative and qualitative measure calculations of the relative impact of the usability issues on the product perception by the users and formulating required priority corrections.

The product owner skills and knowledge is required also to merge the agile approach to usability testing and the required formalism presenting the product and the user interface to the end users, which are outside the organization and so not follow agile principles. The same issue can arise talking to designers if the activity is outsourced as designers and product owners have different needs, which can be placed on opposite sides following the agile manifesto [10].

Demo

An important quality assurance stage is the validation via functionality visualization and comparison to the product owner expectations during the demo sessions. It is a well-known agility practice to correct the implementation route until the desired product is produced or to ensure correct understanding by the team members of project goals. This is an important transparency step allowing both tracking of the progress of the project and visualizing achieved milestones in features development. What is not common in this process is the prolonged involvement of the product owner. Traditionally the active contribution of the product owner in the demo process is limited to the demo session, during which he actively asks questions and accepts the developed features or asks for corrections. In the reality the product owner, stressed by other tasks and commitments, is unable to switch quickly and rapidly to the demo process and dedicate himself completely to it. In the result the acceptance is done only formally, uncertainty in form of acceptance debt is introduced. It is mainly resolved at the final stage of the project when the product acceptance is begun, and much extra work is discovered as new features are demanded and what was perceived as previously agreed requirements are revised.

Therefore the important product owner responsibility is to prolong the acceptance time from the session only to a longer period of days and by doing so dedicate time to review what was demonstrated before. This allows him to reflect thoroughly on his own knowledge and expectation, having been shown all the features. This way the acceptance will be more advance and the reaction more complete, thus avoiding the production of a functionality acceptance debt. The product owners who practice the "next day reflection" reported to the author that they are able to find and bridge expectation gaps much better than when they were restricting themselves only to demo sessions.

Maturity

As the testing in the agile is done starting from earlier stages and product owner is involved into the validation process, the person in that role has another opportunity: validate the maturity of the functionality to identify both functionalities required further development and the obsolete one. One important mistake that software project owner does is keeping the unnecessary or rare functionality mostly been unable to depreciate something the team spent time on. Although the team may dislike such activity it is important to make such move and free up the testers team from verifying something nobody is going to use. It is important to see the testing process through testers' eyes as we do designing the product with users in the "co-design" principles [12] to avoid the "waste". It is also important to follow the status and deal early on uncertainties that can be already resolved avoiding creating the testing debt. It is possible to follow the standard process maturity approach [13] and uncertainties validation [14] applying them to the verification and validation area and the only responsible and knowledgeable person to do it is the product owner.

Conclusions

In this paper we have presented the product owner responsibilities located beyond traditionally mentioned in the agile practices. We have concentrated on inner software engineering activities mainly project assurance related.

The product owner commitment during planning and organizing test cases is extremely valuable. During preparation for these stages he has the responsibility to spread the domain knowledge within the team through both initial and periodic updates, form and keep up-to-date the knowledge base, and both revise and contribute to the project backlog. His priorities and opinions are very important for saving time and efforts allowing the team to concentrate on the truly needed functionality. This results in valuing working software over pseudo-completed features not meeting customer expectations. An interesting responsibility of the product owner lies in organizing the prototyping, where he decide on the form, selects prototype features, organizes the focus group and leads the process.

The definition of how the product owner affects the team members and the quality assurance process is valuable in developing the software organization, as it enables the test process to address more precisely the desired features and be closer to verifying the product on customer expectations than before. This information may become crucial defining the new test or software engineering process, planning responsibilities and load of team members over the project timeframe using the agile development methodologies.

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Micro Design and Value Analysis. The Selection of the Material for Die

Florin Chichernea and Ana Vețeleanu

Abstract

The selection of a material for an application in engineering or its replacement with another material, superior in terms of engineering, economics and environmental impact is an important stage in the design process of a product. The present paper presents a modern and original method for optimizing the selection of the material needed to obtain a new product—for maximizing its performance and minimizing its cost—to obtain the sustainable development objectives. The work strategy involves setting the functions of the product, the matrix and the related programs to select the optimal material from the existing database, applying the value analysis approach for obtaining a material for the selected product, for optimizing the product's value–performance/cost ratio. For the automation of calculations and ease of design work, the authors have developed calculus programs/software. The literature presents techniques for selecting materials in order to obtain a new product or for finding a new material for a given product but the complexity of the problems specific to the selection process leads to new research. Based on our experience in the field, on the relevant examples for applying the Value Analysis approach to industrial products, we, the authors, submit a paper that is a challenge for different fields of expertize and which contributes to this new emerging field of "material selection".

Keywords

Value • Modelling • Value analysis • Optimization of chemical composition • Selection strategies • Design • Materials

Introduction

In our society everything revolves around the notion of Value. In engineering the Value is the judgment made on the product, based on user expectations and motivations, expressed by a dimension that increases or remains at least equal when the satisfaction of user needs increases and/or the product related expenses decrease. An approach which uses and operates with the notion of Value is Value Analysis.

Value Analysis is an organized and creative competiveness method aimed at meeting the user needs using a specific design, functional, economic and multidisciplinary approach.

The Value Analysis Methodology was born in 1947 at General Electric [1]. Value Analysis was quickly used in industries facing economic and strategic deficiencies.

The guideline of Value Analysis is the Functional Analysis.

The object of Value Analysis is the activity, the product or its components. Only the product bears value and its subassemblies or components contribute to the usefulness of the product [2–8].

Based on the experience in the field and the relevant examples of the application of the Value Analysis approach for industrial products [9–11], the authors suggest a new method for optimizing the selection of materials.

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_70,

Optimization is made by establishing the functions of the components, of the operations that have as effect the modification of the structure and implicitly of the material's properties accompanied by a cost reduction without affecting the properties.

Selection of Materials

The selection of a material for its application in engineering or replacing it with another material superior in terms of engineering, economics and environmental impact is an important stage in the design process of a product. In high-tech enterprises these choices can control the costs and the performance of all components and of the assembly [12, 13].

The material selection is performed during the technical design stage and it may be replaced during the experimenting and testing period of the laboratory prototype, depending on its behaviour to strains.

The criteria for material selection are multiple: purpose, operational strains, technological possibilities, working environment, production type, reliability, aesthetics, supply opportunities, cost, etc.

One aspect of optimizing the design process for a product is the selection of the materials and the processes that best meet the functional and engineering requirements and which maximize performance and minimize cost.

Recomanded Steels for Hot Deformation Dies

The selection criteria for the metal alloys used for manufacturing the tools for hot plastic deformation are as follows: high tenacity (resistance to mechanical shocks), hardness (provides wear resistance) and high resistance to high temperatures (thermal shocks).

The steels used in manufacturing hot deformation dies must have the following properties:

- high hot stability,
- high tenacity that ensures the steel's high resistance to brittle fracture,
- high resistance to oxidation, decarburization,
- high resistance to corrosion under stress,
- high resistance to fatique and wear,
- resistance to small plastic deformations,
- satisfactory machinability by plastic deformation and cutting.

The range of standardized Romanian steels for hot deformation dies includes especially medium alloyed steels with Cr–Mn–Si, Cr–Mn and W, Cr–Mn–W–V or W–Cr–Mn and W–V–Mo with reduced content of nickel and less carbon (0.3, …, 0.6 %).

The final thermal treatment and especially the recovery have a special influence on the operating characteristics of such steels. Frequently these tools are submitted to nitriding hardening, in order to increase the resistance to wear, when the characteristics of resistance to shock are provided by the thermal treatment previously applied [12].

Functional Analysis

The functional analysis generally involves the following phases and operations: identifying the functions, grouping and ranking the functions, determining the nature of the functions, rigorous formulation of the functions, validating functions, characterizing and specifying functions, ranking and weighting functions and the functional specification.

Functional Deductive Analysis

A function is a relation established between the product and its environment. From the dynamic articulation of the questions "Why?, When?, How?" results in the FAST functions tree (Function Analysis System Technique). From necessity to functions then to solutions.

The FAST diagram allows the presentation for a VA (value analysis) product of a solution, of the functions in a logic chain, answering the questions above.

Figure 1 shows the FAST diagram for the application presented in this paper.

Following this analysis applied to the materials intended for manufacturing the hammer forging dies for hot deformation, the following functions are noted (Table 1).

In order to select a material used to manufacture the dies, the authors have created two programs to automate the calculations [14].

In this article the authors highlight and present:

1. the particular role of applying the Value Analysis approach to a tool steel,
2. the working mode for optimizing the value/cost ratio,
3. a valid and useful guide for the specialists to optimize the value/cost ratio of the alloys for parts.

Value Analysis Approach

The object of the Value Analysis is the activity, product or its components. The product is the only one bearing value and its subassemblies or components contribute to its utility.

Therefore, apparently a part, a component of an alloy could not be approached using the Value Analysis approach. However, if we penetrate within its structure [15], at micro level we notice that our part is made of several constituents, of several components (Fig. 2).

We call these constituents subassemblies and components of our part, which is an assembly at micro level.

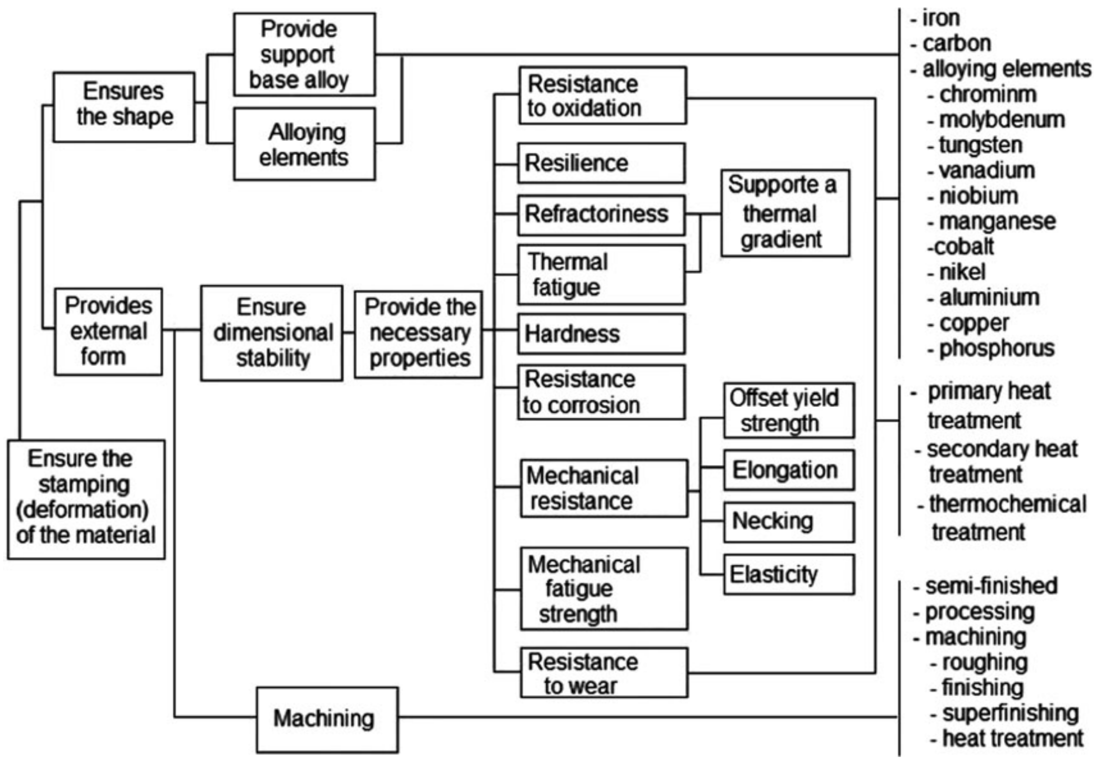

Fig. 1 The FAST diagram

Table 1 The classification of the functions

Symbol	Functions
F4	Provides resistance to wear
F9	Ensures the shape
F7	Provides resistance to mechanical and thermal fatigue
F2	Provides hot stability
F5	Provides hardness
F8	Provides resistance to oxidation
F3	Provides mechanical resistance
F1	Provides resilience
F6	Provides resistance to corrosion
F10	Supports the assembly

In the case of an assembly with several constituents/alloying elements we can apply the Value Analysis approach to this 1assembly, which is the alloy of the part.

Constituents/alloying elements and heat treatment operations, to a certain extent, contribute each to the increase or decrease of some properties of the part's alloy.

At this point, three important specifications must be made:

1. it is taken into consideration an assembly, to which the Value Analysis approach can be applied, the part's alloy and not the actual part,
2. each alloying element and each heat treatment operation costs,
3. this approach, to the knowledge of the authors, is unique and the first of this kind in the specialty literature.
4. The actual approach of the Value Analysis is not presented as it is already known.

There shall be presented the iterations and conclusions drawn from applying the Value Analysis approach in the assumptions described above.

Table 1 shows the classification of the functions starting from the functional analysis of the product—respectively—the alloy of the die.

Iteration 1: Value Weighting of the Functions

Throughout the two iterations of the Value Analysis there shall be kept the 10 functions outlined in Table 1.

Table 2 shows the value weighting of the functions.

The authors have developed a program/software that calculates all the values from the shown tables and draws all the diagrams necessary for presenting the findings, in all the iterations of the approach. The calculus is made using the least squares method.

Economic Dimensioning of the Functions

The 30VCrW85 steel is chosen to exemplify the Value Analysis approach.

The chemical composition of the steel is given in Table 3 and the costs of the alloying elements are shown in Table 4.

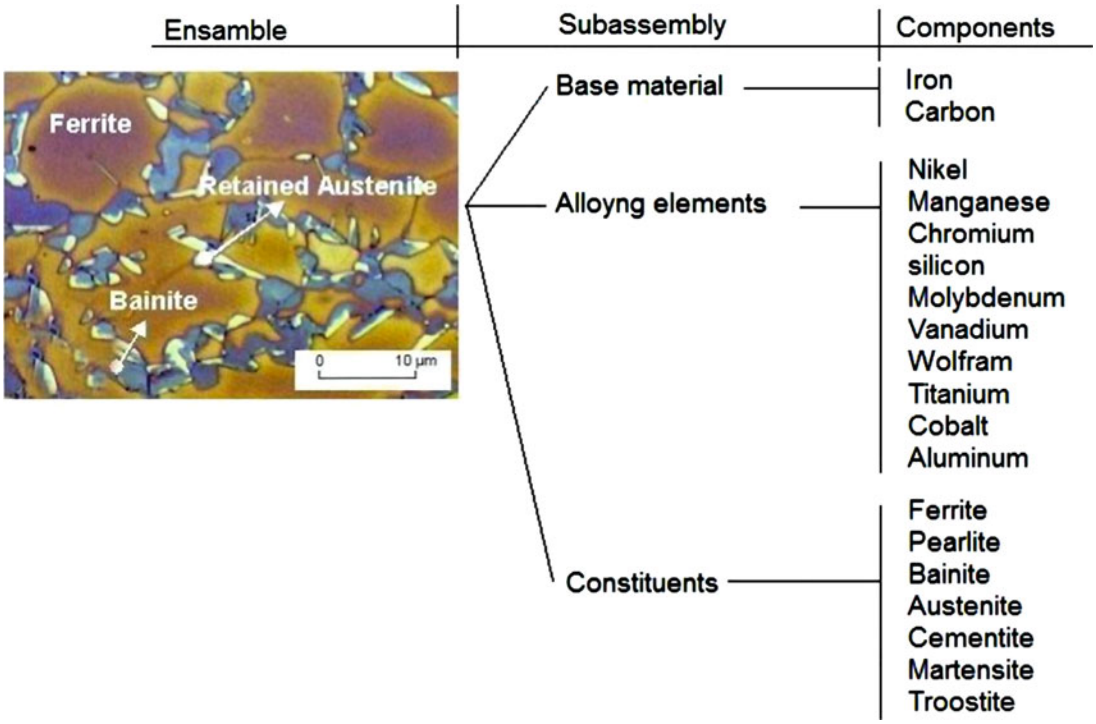

Fig. 2 The assembly of the part alloy

Table 2 Value weighting of the functions

Functions	F4	F9	F7	F2	F5	F8	F3	F1	F6	F10	Total
Percentage (%)[a]	18.2	16.4	14.5	12.7	10.9	9.09	7.27	5.45	3.64	1.82	100

[a]Coordinate (X)

Table 3 Chemical composition of steel 30VCrW85

Steel	Fe	C	Mn	Si	Cr	Ni	V	W
30VCrW85	87.27	0.25–0.35	0.20–0.40	0.15–0.3	2.5–2.8	0.35	0.3–0.4	8.0–9.0

Table 4 The total cost of the alloy part in iteration 1

	Components (%)								
Steel	Fe	C	Mn	Si	Cr	Ni	V	W	Total
30VCrW85	87.27	0.30	0.30	0.23	2.70	0.35	0.35	8.50	100
Weight (kg)	87.27	0.3	0.3	0.23	2.7	0.35	0.35	8.5	1000
Total cost ($)	1.8	6.62	3.2	2.75	5.5	17.15	24.5	44	564.0

For a proper allocation of costs, Table 5 shows the influence of alloying elements on the properties of the tool steel.

The allocation of costs to functions was performed in the matrix functions—costs from Table 6.

In Table 6 the cost is distributed on the function/functions it is part of.

In the first iteration the steel has:

– alloying elements in the minimum percentage of the standardized range,
– there are applied:
– a primary thermal treatment,
– a secondary thermal treatment for vacuum hardening + recovery,
– a thermochemical treatment.

Table 5 The influence of alloying elements and heat treatment on the properties-functions

Properties alloying elements	Resilience	Heat stability	Strength	Resistance to wear	Hardness	Resistance to corrosion	Machinability by cutting	Mechanical and thermal fatigue resistance	Deformability	Resistance to oxidation
Functions	F1	F2	F3	F4	F5	F6	F10	F7	F10	F8
Silicon	↓	↑	↑	↓	↑	-	↓	↑	↓	↑
Manganese in pearlitic steel	-		↑	↑↓	↑	-	↓		↑	
. . .	. . .									
Thermochemical treatment	-		↑	↑↑↑	↑↑↑	↑↑↑	↓	↑↑	↓	↑↑↑

↑ small increase, ↑↑ average increase; ↑↑↑ large increase, ↓ small decrease, ↓↓ average decrease; ↑↓ increase to a value followed by a decrease of properties from that value

Table 6 Cost weighting of the functions

Parts	Cost of parts[a]	Functions F4	F9	F7	F2	F5	F8	F3	F1	F6	F10
Iron	158.76	31.75	55.57	23.81	0	0	0	22.226	15.876	1.5876	7.938
...											
Total cost	845.89	182.1	161.1	109.2	75.86	71.52	65.93	113.9	32.38	22.13	11.84
Ratio		0.215	0.19	0.129	0.09	0.085	0.078	0.135	0.038	0.026	0.014
Cost of functions (%)[b]		21.5	19	12.9	8.97	8.46	7.79	13.5	3.83	2.62	1.4

[a]Cost ($)
[b]Coordinate (Y)

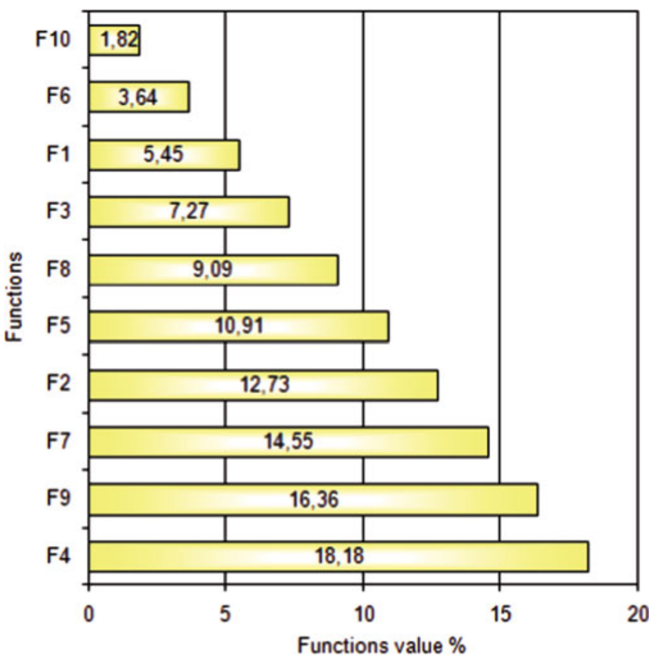

Fig. 3 Value weighting of the functions

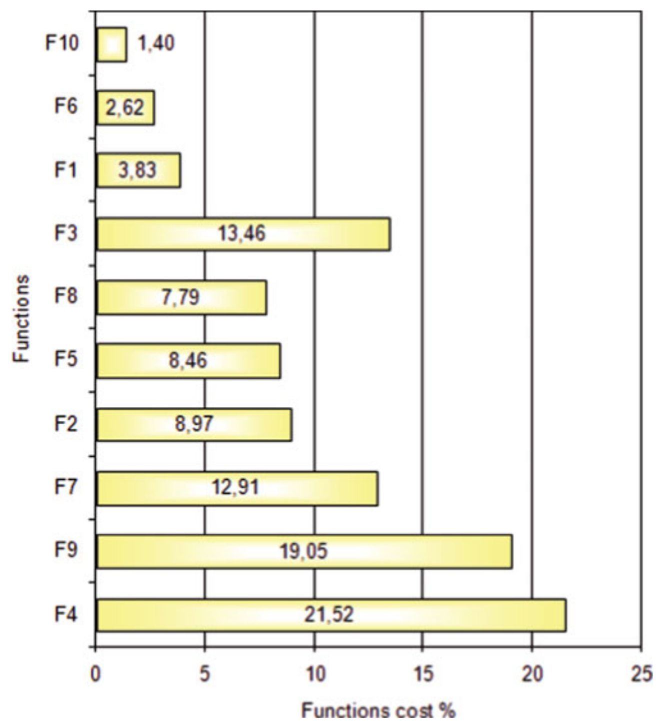

Fig. 4 Cost weighting of the functions

Comparison/Weighting Functions in Value and Cost

The check of this identity is performed using regression analysis by determining the linear function (the regression line) that represents the average proportionality.

The regression line passes through the origin, as it is considered that a function with “0” value costs “0”.

The line has the shape: $y = a * x$ (1)

In the case of perfect proportionality all points are on the line (1). In order to simplify, the calculation is tabulated.

The coordinates x_i and y_i are given in Tables 2 and 6 and based on the data calculated the diagrams from Figs. 3, 4 and 5 are drawn. The values of the parameters are as follows: $a = 1.02$, $\alpha = 45.6$, $S = 84.49$, $S' = 0$.

From Tables 2 and 6 are extracted the required values that help draw the following types of diagrams:

- the value weighting of the functions diagram (Fig. 3),
- the cost weighting of the functions diagram (Fig. 4),
- the cost and value weighting of the functions diagram (Fig. 5).

The diagram in Fig. 3 shows the value ranking, prioritization and weighting of the functions.

The assessment of the functions which is shown in Fig. 4 highlights the most expensive functions.

The diagrams allow comparisons between the total costs of the functions and, within the total costs, there are highlighted:

- the very expensive functions, with the highest weighting in the total cost of the product,
- the functions whose implementation requires disproportionate costs as compared with other functions.

The diagram shows a Pareto type distribution, i.e. 20–30 % of the total number of functions comprises 70–80 % of the total cost of functions.

These functions are shown in the example from Fig. 4, functions F4, F9, F7 and F3.

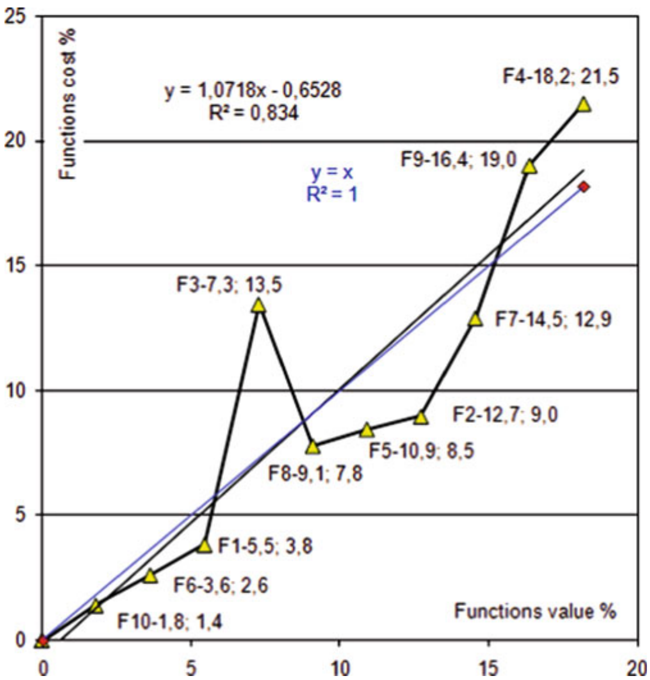

Fig. 5 Weighting of the functions in value and cost

If there is such a distribution, the first functions in the order of costs, representing 20–30 % from the total number of functions, the functions are considered expensive.

The diagram in Fig. 5 shows:

- the regression line drawn using the method of the least squares and
- the comparison of functions in terms of value and costs.

In diagram from Fig. 5 the following lines can be seen:

- the equation line y = x (the first bisector) the line that averages the weighting of functions in value and cost, expresses the ideal situation of the disparity between the two weightings, the weighting of functions in value and costs,
- the regression line of equation y = 1.0718 * x–0.6528, which approximates the arrangement of the points, expresses the real situation of the disparity between the two weightings, the weighting of functions in value and costs,
- functions F4, F9 and F3 are situated above the lines aforementioned. The weighting of the cost is larger than the weighting of the value of these functions.

These functions are deficient and attention should be focused on them. The cost of these functions should be reduced.

Discutions/Comments

The estimator S' is actually an "entropy" that characterizes the system's degree of disorder. A basic criterion of Value Analysis is to obtain a minimum value for S'. In order to reduce the estimator S' the points should be aligned as perfectly as possible on the equation line y = a* x with a sloping angle of 45° from Fig. 5.

Firstly, there shall be redesigned the functions that are placed above the regression line (1), in order to decrease their cost.

For the points situated below the line, the matter is more complicated. By decreasing the cost of the functions situated above the line, the latter might have a different slope and the points initially situated under the line might get above it. It is also obvious that, by decreasing the cost of these functions, the total cost of the product decreases leading to the automatic increase of the weighting of the functions whose cost has not changed. This is another reason due to which some points situated below the line can get above it without modifying in any way the absolute dimension of the costs of the functions.

Secondly, the minimization of S' must be interpreted as much possible as an increase of the value/cost ratio.

Thirdly, in the Value Analysis might be admitted the increase of the cost of some functions provided their value increases faster than costs.

Basically, the criterion of minimizing S' often leads to carrying out the Value Analysis studies in cascade, the optimization of the constructive solution being thus an iterative process. There are analysed first of all the functions situated above the regression line (1) and these are made cheaper, the regression line is drawn again and afterwards is found that other functions are above it; these functions are analysed looking for solutions to decrease their cost and the regression line is drawn again, etc., the constructive solution being improved from one iteration to another.

In the second iteration of the Value Analysis approach there shall be considered the functions situated above the ideal regression line (1): F4—Provides resistance to wear for the die, F9—Ensures the shape of the die, F3—Provides tensile strength.

Iteration 2: Economic Dimensioning of Functions—Comparison/Weighting Functions in Value and Cost

For the second iteration there shall be presented only the results in tabulated form. The weighting of the functions in value is the same as for the first iteration as no functions were added or removed from the system (Table 5).

As the functions that cost more are highlighted in Fig. 5, solutions shall be suggested for reducing the cost of these functions.

The cost of these functions can be reduced by answering the following questions:

- can there be used less expensive alloying elements?

Table 7 Cost weighting of the functions

Parts	Cost of parts[a]	Functions F4	F9	F7	F2	F5	F8	F3	F1	F6	F10
Iron	155.61	31.1	54.5	23.3	0	0	0	21.7	15.5	1.55	7.78
Total cost	791.89	181.3	131.6	106.3	82.99	62.3	72.73	106.7	32.48	3.278	12.17
Cost of functions (%)[b]	22.9	16.6	13.4	10.5	7.87	9.18	13.5	4.1	0.41	1.54

[a]Cost ($)
[b]Coordinate (Y)

- can certain too expensive alloying elements be eliminated?
- can the quantity of alloying materials be decreased?
- can the thermal regimes of the thermal treatments be reduced (duration and temperature)?
- can a thermal treatment operation be eliminated?
- can another thermal or thermo–chemical treatment operation be used?
- can the die be processed by cutting at a lower price?

These questions must be answered in such manner so that the properties, characteristics and performance of the die's alloy are not affected, but improved if possible!

In our study, in the second iteration, actions were taken for the following cost elements:

- the alloying elements are to the maximum (Table 3),
- the termo-chemical treatment is eliminated,
- the primary thermal treatment is replaced with a thermal treatment in stages,
- a secondary thermal treatment (hardening + recovery).

The allocation of costs to functions was performed in the functions—costs matrix from Table 7.

Coordinates x_i and y_i are given in Tables 2 and 7 and, based on the data calculated, the diagrams from Figs. 6 and 7 are drawn. Parameter values are as follows: $a = 1.03$, $\alpha = 45.8°$, $S = 87.44$, $S' = 0$.

From Tables 2 and 7 are extracted the required values that help draw the following types of diagrams:

- the diagram of weighting functions in value (identical with Fig. 3—iteration 1),
- the diagram of weighting functions in cost (Fig. 6),
- the diagram of weighting functions in value and cost (Fig. 7).

The critical assessment of the functions presented in Fig. 6 highlights the most expensive functions.

The diagram in Fig. 7 represents the regression line drawn using the least squares method and presents the comparison of functions in terms of value and cost.

In the diagram from Fig. 7 there can be seen the following lines:

- the equation line $y = x$ (the first bisector), the line that averages the weighting of functions in value and cost, expresses the ideal situation of the disparity of the two weightings, the weighting of functions in value and cost,
- the regression line, of equation $y = 1.105 * x–0.955$, which approximates the arrangement of the points,

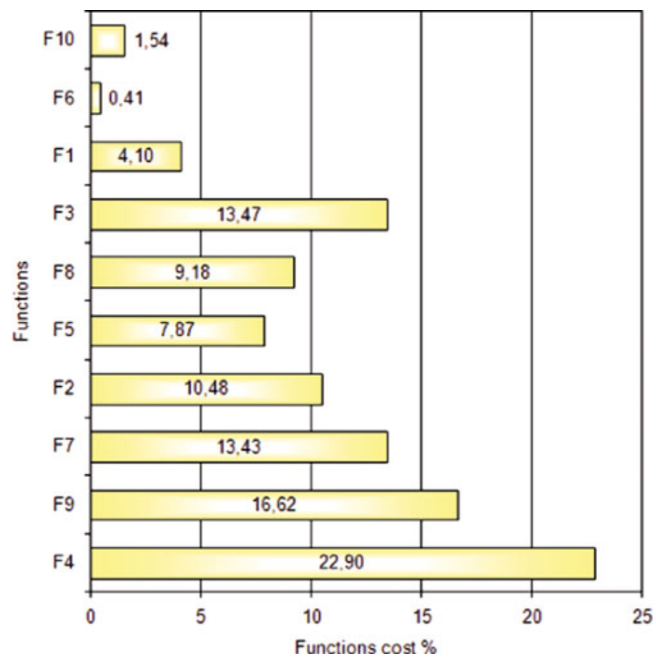

Fig. 6 Cost weighting of the functions

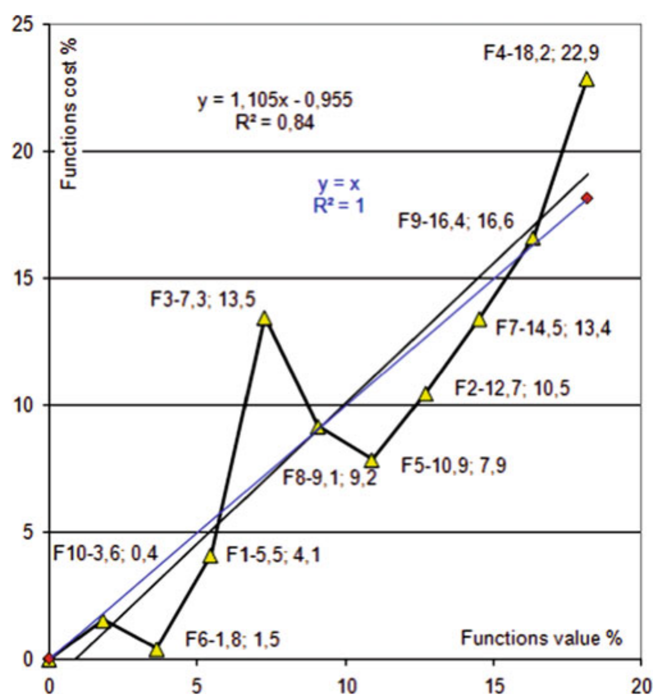

Fig. 7 Weighting of the functions in value and cost

expresses the real situation of the disparity of the two weightings, the weighting of functions in value and cost.
– functions F4 and F3 are situated above the lines aforementioned. The weighting of the cost is larger than the weighting of the value of these functions.

These functions are deficient and attention should be focused on them.

The cost of these functions should be reduced.

Discutions/Comments

Following the second iteration there can be seen in Fig. 7 that the value of some functions increased, of other functions decreased, but the cost of those that increased eventually decreased due to the decrease of the cost of the "product"/material.

The functions F4 and F3 are situated above the regression line.

There can be seen comparatively to Fig. 5 (iteration 1) in Fig. 7 (iteration 2) that the functions are grouped closer to the ideal regression lines.

Function F9—Ensures the shape of the die and it is situated on the line of ideal regression but has numerous possibilities of decreasing the cost.

Below are presented comparatively the equations of the regression lines (the real situation) and the correlation coefficients R^2 for the two iterations:

Iteration 1: $y = 1.0718 * x–0.6528$, $R^2 = 0.834$,
Iteration 2: $y = 1.105 * x–0.955$, $R^2 = 0.84$,

There can be seen an increase in the value of the correlation coefficient R^2 in the second iteration as compared to the first iteration, thus resulting that the dispersion of the points decreased in relation with the regression line.

The iterations continue until the correlation coefficient R^2 tends to value 1 and the regression line (the actual situation) tends to $y = x$ (the ideal situation).

Results

In two iterations of the Value Analysis study our product was redesigned and optimized in terms of:

1. engineering:
   – the percentages of the alloying elements were modified from a maximum percentage to a minimum,
   – the termo-chemical treatment was eliminated,
   – the primary thermal treatment was replaced with a thermal treatment in stages.
2. economics:
   – the cost of the product decreased from 845.89 $, in the first iteration to 791.89 $ in the second iteration, a 6.38 % decrease,
   – the cost of function F4—Provides resistance to wear for the die, increased by 6 % in the second iteration, as compared to the first iteration, but the cost of the product decreased by 6.38 %,
   – the cost of function F3—Provides mechanical resistance, increased by 0.1 % in the second iteration as compared to the first iteration, but the cost of the product decreased by 6.38 %,
   – the cost of function F9—Ensures the shape of the die, decreased by 19.05 % in the first iteration, to 16.62 % in the second iteration, a decrease of 12.75 %,
   – the cost of function F5—Provides the hardness of the die, decreased from 8.46 % in the first iteration, to 7.87 % in the second iteration, a decrease of 6.9 %,

In the third iteration of the Value Analysis study there shall be analysed the functions situated above the regression line $y = x$, (F4—Provides resistance to wear for the die, F3—Provides mechanical resistance and F9—Ensures the shape of the die), there shall be analysed the "components" participating to achieving these functions and solutions shall be proposed for reducing the costs.

For functions F4 and F3 there shall be searched alloying and thermal treatments elements that decrease their cost, but maintain the qualities and the properties of the die material.

For function F9 there shall be searched procedures for the mechanical processing of the cheaper die, and this shall be the subject of another paper.

Applications

This guide can be used for optimizing the value/cost ratio:
– different types of alloys for the parts (cast iron, steel, aluminium alloys, copper alloys, etc.),
– composite materials.

It is important to achieve:

1. the functional modelling (using functions) of the alloy (viewed as a whole) within the Value Analysis approach,
2. the valorisation of the alloy's functions,
3. the allocation of the cost of a alloy/assembly constituent to the functions it is part of,
4. the manner of interpreting the results from the diagrams that represent the weighting of the functions in value and cost,
5. the proposal of variants with a lower cost for:
   (a) alloying elements,
   (b) applied heat treatment operations,
6. the working manner using the programs made available by the authors.

Conclusions

The design of a mathematical—economic model for taking some decisions on the optimization of the alloying elements percentage, on the manner of applying the heat treatment in the case of some alloys in terms of Value Analysis approach is an absolute novelty in the field.

This modelling has an important role as it opens a wide range of engineering applications.

The modelling of the Value Analysis products, having various applications from engineering, medicine to services has brought in the last 65 years of applications undeniable progress.

With this study, the Value Analysis makes an important step in the world of "micro assemblies", it opens new horizons of applications and keeps up with the directions of science to penetrate in micro design word.

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The Internet of Things in Community Safety and Crime Prevention for South Africa

Nomusa Dlodlo, Paul Mbecke, Mofolo Mofolo, and Martin Mhlanga

Abstract

One of the major tasks of the South African (S.A.) government is to reduce crime levels on a year-to-year basis. The use of information and communications technologies (ICTs) is capital in facilitating the process to finding solutions to crime. This paper is about taking advantage of a particular subset of ICTs that is referred to as the internet of things (IoT) and is integrated with biometric technologies in the fight against crime. The paper identifies not only the sectors of the economy that fall under community safety and crime prevention such as police efficiency and accountability, and partnerships between the police and communities, but also a number of IoT including biometric applications that can be of value in these sectors. By drawing on the characteristics of identified IoT including biometric applications, the research came up with the architecture of an integrated biometric IoT system for tracking parolees who have violated their bail conditions, as a case study for the S.A. environment. Parolees are tagged with tracking devices which are GPS-enabled for location of the parolee at any point in time.

Keywords

Internet of things • Community safety • Crime prevention • Biometrics • Information and communication technologies

Introduction

Crime is a prominent issue in South Africa (S.A.). During 2010/2011 year alone, a total of approximately 2.1 million serious crimes were registered in South Africa [2]. One of the major tasks of the S.A. government is to reduce crime levels on a year-to-year basis. The use of information and communication technologies (ICT) is capital in facilitating the understanding of and assisting the process to find solutions to crime. This paper is about taking advantage of a particular subset of ICT that is referred to as the internet of things (IoT) in the fight against crime.

CASAGRAS defines the IoT as [1]: "A global network infrastructure, linking physical and virtual objects through the exploitation of data capture and communication capabilities. This infrastructure includes existing and evolving internet and network developments. It offers specific object-identification, sensor and connection capability as the basis for development of independent federated services and applications".

The objective of this paper is to showcase the integration of IoT in community safety and crime prevention. It draws on the characteristics of identified IoT applications and biometric systems to come up with the architecture of an integrated biometric IoT system to track parolees who have violated their bail conditions. This paper is organised as follows: the next section is the methodology. We explore related biometric systems in section three. We explore community safety and crime prevention concepts and systems in section four. The fifth section is on the architecture of

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_71,

the IoT biometrics system to track parolees, while the last section is a summary of the paper.

Methodology

Crime is a big threat to the safety of South African communities. This study is an extension to the efforts that South Africa is making towards crime prevention and community safety. The study proposes enhanced adoption of IoT including biometrics in community safety and crime prevention. The question that this research answers therefore is:

> What role can IoT technologies enhanced with biometric technologies play in community safety and crime prevention in South Africa?

The objectives of the research are:

- To facilitate an understanding of the subject area through examples of IoT and biometric applications that can be adopted in community safety and crime prevention initiatives
- To develop an architecture for a biometrics-based system that tracks parolees as a case study of the application of IoT in community safety and crime prevention

A literature survey was conducted through internet searches to identify applications that could be adopted in the South African environment for law enforcement, situational crime prevention and social crime prevention. From the identified IoT including biometric applications, certain characteristics were identified which contributed to the development of the architecture of the system that constitutes our case study on the tracking of parolees.

Related Biometric Systems for Tracking People

This section reviews related biometric systems that will provide input to the architecture developed later in this paper. Biometrics is the science of identifying people using physiological features such as fingerprints, DNA, palmprint, iris recognition, voice and handwriting.

A distributed biometric identification system incorporates highly mobile workstations and a file server remotely located from the workstations [5]. The workstations receive input biometric data such as fingerprint and photographic data, and sends that biometric data to the remote file server. The file server compares the input biometric data with stored biometric data to determine any matches. The results of the comparison are provided to the workstation that requested the comparison. Workstation mobility is enhanced by providing a wireless and/or PSTN communications link between the workstation and the remote file server.

A computer-based customer-tracking system uses a passive biometric identification for identifying customers [4]. Data on the customer is not captured manually but identification is wholly biometrical. Biometric information is sent to a central computer processor which searches files in a library for matching biometric data. If a match is not found, then the processor opens a new file in the library.

A gaming system is provided with biometric facilities for identifying a player [10]. Biometric data is stored in a portable biometric device such as a smart card and left in the possession of the individual to whom the biometric data relates. The reference biometric data on the card is read by individual gaming terminals when a player comes in close proximity with the terminal and processed.

Multimedia surveillance systems can be enriched with biometric technology; the best view of detected persons and their extracted visual features (e.g. faces, voices and trajectories) can be exploited for people identification [3].

Dialog Communication Systems developed a BioID [9], a multimodal identification system that uses three different features—face, voice and lip movement to identify people. With its three modalities, BioID achieves much greater accuracy than single-feature systems. If one modality fails, the other two modalities lead to an accurate identification.

Applications of IoT in Community Safety and Crime Prevention

South Africa's National Crime Prevention Strategy (NCPS) [14] acknowledges the importance of social, developmental and environmental causes of crime and therefore the necessity of addressing social, developmental and environmental factors that promote crime. For each of the community safety and crime prevention areas of police efficiency and accountability, and partnerships between the police and community initiatives, a number of IoT applications are identified as follows:

Police Efficiency and Accountability

This section looks at IoT technologies that assist improve police efficiency and accountability

- Biometric identification

Biometric identification consists of methods for uniquely recognising humans based upon one or more physical or behavioural traits. Physiological characteristics include fingerprint, face recognition, DNA, palm print, handwriting, iris recognition and odour. Behavioural characteristics include voice and gait, to name but a few.

Police agencies across the world are using mobile biometric fingerprinting for forensic identification. Fingerprint scanners identify suspects and victims more quickly. The devices use cellular technology. Fingerprints are scanned and instantly matched against a database containing over a million prints for comparison. Scanners can be used to:

- Identify a suspect in a crime scene
- Identify victims of motor vehicle accidents
- Identify suspects carrying false or no identity documents
- Identify a homicide victim instantly without having to wait for autopsy results

EuroSmart is working on standardisation and harmonisation of the workflow and technologies used in the border control process, in order to achieve the right level of interoperability, an equivalent level of security at all borders and a common interface for all travellers. E-passports are biometric passports. The passports provide passive authentication, basic access control security and biometric face image. The European Union (EU) member states have moved to biometric passports with extended access control security protecting access to fingerprint images. E-gate programs are running in 20 countries. They use biometric identification/authentication. At present 3 major biometric technologies are widely used, i.e., fingerprint, face, iris, vein pattern [8].

- Fraud detection

In South Africa currently, for fraud detection, some banks are linking to the Home Affairs National Identification System (HANIS) which enables biometric identification of current and prospective clients. This service enables banks to verify and authenticate client identity, thus limiting identity fraud.

- Alcohol detection

In New Mexico, the Driver Alcohol Detection System for Safety (DADSS) breathalyser-based interlocks in vehicles are attached to the ignition that prevents a car from starting pending breathing into a tube for a minute to determine blood alcohol levels [7].

Touch spectrometry technology seeks to measure blood alcohol levels via near infrared light which penetrates the epidermis to analyse the composition of the fluids present in the dermis layer of the skin.

Matt Legget invented a jacket that can tell if one is too drunk to drive. They blow into a nozzle that is hidden in the collar. Inside the jacket is an Arduino microprocessor, an alcohol sensor and a series of LEDs. A breathalyser situated in the jacket pocket analyses the breath samples and then lights. The LED glows only when alcohol is detected and the brighter the glow the worse.

Drager interlock XT [6] is a breath alcohol measuring instrument with a vehicle immobiliser. It prohibits a driver who has consumed alcohol from starting the motor car. The Drager interlock XT comprises 2 main components: the breath-alcohol measuring with the measuring system, which is situated in the vehicle and the control unit which is installed under the dashboard and allows or prevents current being supplied to the vehicle starter system.

- Surveillance

Closed circuit television camera (CCTV) are used to monitor activities in many important public places like airports, rail stations, business offices, city centres, sports events. They are used to capture and record images for security and surveillance purpose. CCTV cameras can be wired or wireless. However, there are many advantages of wireless CCTV over wired CCTV. One of the benefits of a wireless camera is that it is free from interruption caused by the wires. Wires could be damaged or wrongly configured that could cause the interruptions of the camera function.

In S.A., ATM bombings have increased 300 % in the past 5 years and cost banks millions of Rands in replacing the machine. Banks and cash-in-transit services are increasingly embracing surveillance, off-site monitoring and intelligent alarms. There are over 15,000 ATMs in South Africa. Digital camera surveillance and recording systems are designed for use in both mobile and static applications. These solutions have modern video compression formatting, which is able to deliver high quality video streaming and play back and they support GPRS, GPS, GSM and dial-up connections with modems, as well as the use of TCP/IP for continuous monitoring. In emergency, the latest systems are able to send a signal via up to five different methods of communication, in order to ensure the alarm signals reach the central monitoring station as quickly as possible. Alarms can now be integrated with lighting systems, so that during an alarm situation the lights are automatically switched on, thereby ensuring that CCTV can obtain the best possible clarity, greatly improving the chances of a successful apprehension.

- Anti-hijack

Insurance companies, South African Police Service (SAPS) and Business Against Crime are working together on an anti-hijack system. An anti-hijack system is an electronic device fitted to motor vehicles to deter criminals from hijacking them. A lockout system is activated when the vehicle drops below a certain speed or becomes stationary. A transponder system will disable a vehicle once the driver leaves the immediate vicinity of the vehicle. The flame blaster is a container of petroleum gas which is activated by pushing a button located near the foot pedals, resulting in 3-m long jets of burning liquid.

In a real-time GPS tracking system, a “locate” is when a GPS tracking device sends location coordinates to the tracking system to be marked on a map and recorded with a street address if available. This recorded location with any associated data such as date, time, speed, direction, etc. is called a “locate”. Locates can be generated one of three ways:

- Motion-activated tracking is when the unit only turns on when it senses motions or vibrations and sends out locates at a predefined rate for the time it is in motion and shuts down when no more motion is detected
- Constraint tracking is when a tracking device continues to send locates regardless of whether there is any motion or not
- Location on request is when you only get a location if you send the device a request for it to send back its location

The more locates you get the more dots there are visible on the map. The GPS logger on the other hand is a solution to monitor behaviour of the driver over a period of time. You can only do this by retrieving the GPS logger for the history.

S.A.'s Inkwazi Vehicle Tracking system [12] is a commercial vehicle tracking system. It monitors vehicle activity and reports changes, in real time, to a monitoring control room. It determines accurate geographic positions through GPS and communicates using GSM, SMS and data calls. The unit has an option of adding satellite communication which can be used should the GSM system be unable to communicate.

- Crime statistics

Crime figures in South Africa are currently in a bit of a mess. An example can be borrowed from the US. The New York Times released an interactive map titled Mapping Homicides [13]. The data is compiled from open-record requests and major crime reports from the NY police department, including most homicides in addition to new accounts, court records and additional reporting. The map is updated as new information becomes available. Users can filter the data by month and time of day, race, sex and age of victim or perpetrator, weapon used and the district the crime happened.

The Trulia crime maps [19] in the US cities are interactive geo-located heat maps visualising where crime happens most, what types of crimes those are and when they actually happened. The map includes more than five million data points aggregated from more than 1,000 different sources. Neighbourhood blocks are coloured according to crime density.

Partnerships Between Police and Community

This section looks at partnerships between the police and communities in the fight against crime

- Safe neighbourhoods

Access that national sex offender registry at your fingertips, using GPS technology to locate all the sex offenders in your area. Offender Locator [18] and Offender Monitor [17] in the US helps find sex offenders in the neighbourhood, get informed with detailed records, and receive e-mail alerts of new activity. The information comes from the Home Affairs databases. It includes the convicted crime, birth date and physical profile.

SafeRoute US [16] is an Android-based application that gives GPS-enabled crime statistics and safety levels for every city in the US where enough crime data to report is present. The application even takes it a step further to provide safety levels (safe, moderate, dangerous) for every zip code in select major cities. As long as the Android device is GPS-enabled, SafeRoute will detect exactly where you are and tell if the area is safe, moderate or dangerous. You can press "crime details" to see detailed crime statistics from the city.

A bird's eye satellite view in Google maps can be used to make neighbourhood watch patrol assignment maps, see if a neighbourhood parameter fence has any damage, etc. The services that take advantage of Google Maps, like SpotCrime, which is a free service that shows a detailed history of crimes in and around a neighbourhood can also be utilised.

Most alarms have their signals monitored by an armed response company who work with local police when there is a break-in. The alarm and MMS camera alarm system have all zones named and emergency phone numbers programmed. All that is needed is place sensors in areas that need protection. When movement is detected by a wireless motion detector, the siren sounds. Alerts to cell phones from a landline or GSM, SMS device, MMS to email functions are also available. A standard alarm system uses motion sensors that keep watch over doors, windows and indoor areas.

In crowd control, more and more people are choosing their mobile devices as their first choice for online activity. Increasing access to the sensors on these devices for location and readings on surroundings has made these tools a primary input for data collection activities. In the geospatial real, OpenStreetMap [15] spatial data building effort uses a community of contributors in a crowd sourcing project that spans the globe, using contributors to take charge of their neighbourhood and continuously adapt as their surroundings change.

- Safer schools

For safer schools CCTV cameras, perimeter fences, metal detectors and alarm systems need to be in place. An alarm system can have GPS coordinates, so that when it goes off the control centre can easily locate the site. Electronic fences can either be wireless or in-ground. Wireless fences have an electronic base unit that emits radio waves up to a certain range. A receiver and transmitter send an alert to the relevant body. The in-ground fence picks up radio waves and beeps once someone crosses the fence. Perimeter security can have fibre optic stretched along the fence. An anomaly such as a bend or twist in the fence, no matter how slight, would show a slight variation in the colour of light (different wavelengths

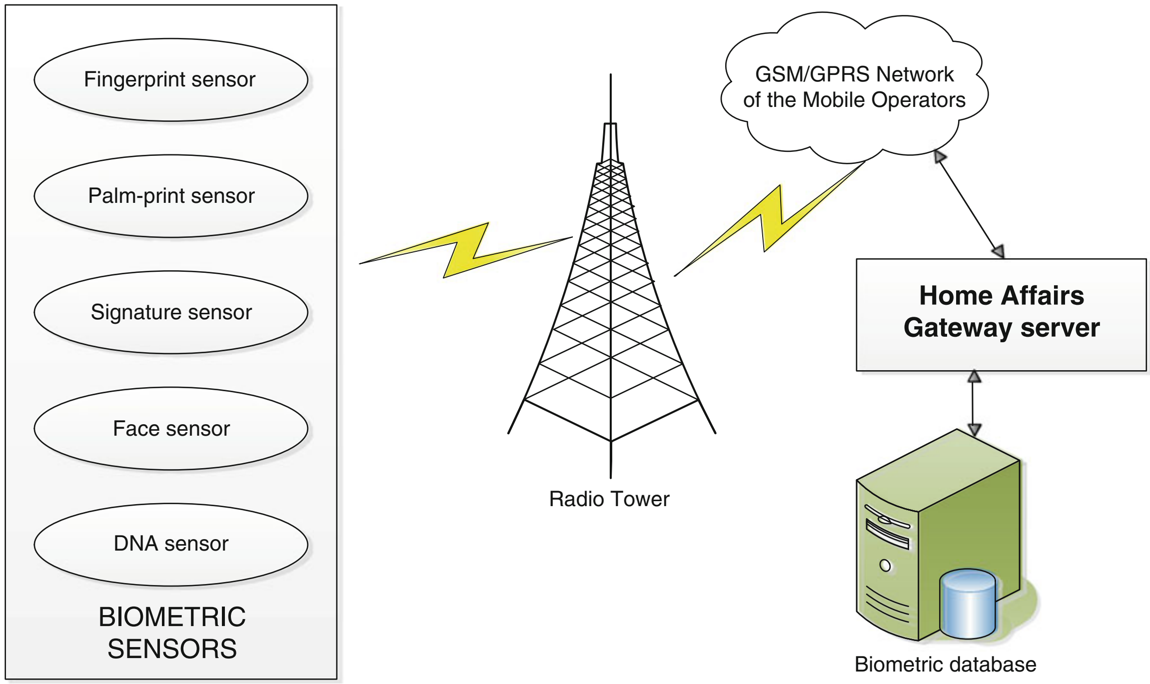

Fig. 1 Biometric identification

contained in white light reflect at different angles). An optical time reflectometer (a type of radar for light) attached to the fiber optic would locate the spot, within about a meter, where the twist or bend took place and a search light could be instantly aimed at the point [11].

Architecture

This section consists of subsections on identified characteristics and the architecture of a biometric identification system and another on the architecture of the parolee monitoring system.

Characteristics Identified

By going through the systems that have been identified in the preceding sections, the following characteristics of the systems which will feed into our architecture were identified.

- Biometric identification based on physical and behavioural traits including fingerprint, face recognition, DNA, palm print, handwriting, iris recognition, voice and gait
- Scanning technologies such as RFID, motes, QR codes, etc, to scan and digitalise these biometric traits
- Comparison algorithms for the matching the digital traits against the biometric data that is collected on all individuals
- Mobile communication technologies such as GPS, GPRS and GSM
- Detection and tracking technologies
- Predictive and decision-making capabilities to interpret the data
- Mechanisms for notification of users.

Biometric Identification System Architecture

Before a person is released on parole, their biometric details are captured onto a National Biometric System that is managed by the Department of Home Affairs. The data, which is either fingerprint, palm print signature, photo of face, DNA, document, etc. is captured by way of a mobile scanner, that is, it can be captured from anywhere at any time. It is then passed on to the central server in the Home Affairs Department through a GSM/GPRS network. GPRS is a packet-oriented mobile data service on 2G and 3G cellular communications to transmit internet protocol (IP) packets to external networks such as the internet. GSM is a global system for mobile transmission for 2G digital cellular networks. See Fig. 1 for the details.

Architecture of the Parolee Monitoring System

When parolees are released they are governed by certain conditions of parole. The parolee is tagged with a tracking device e.g. an radio frequency identifier (RFID) tag in the form of a bracelet. The assumption is that the tracking device

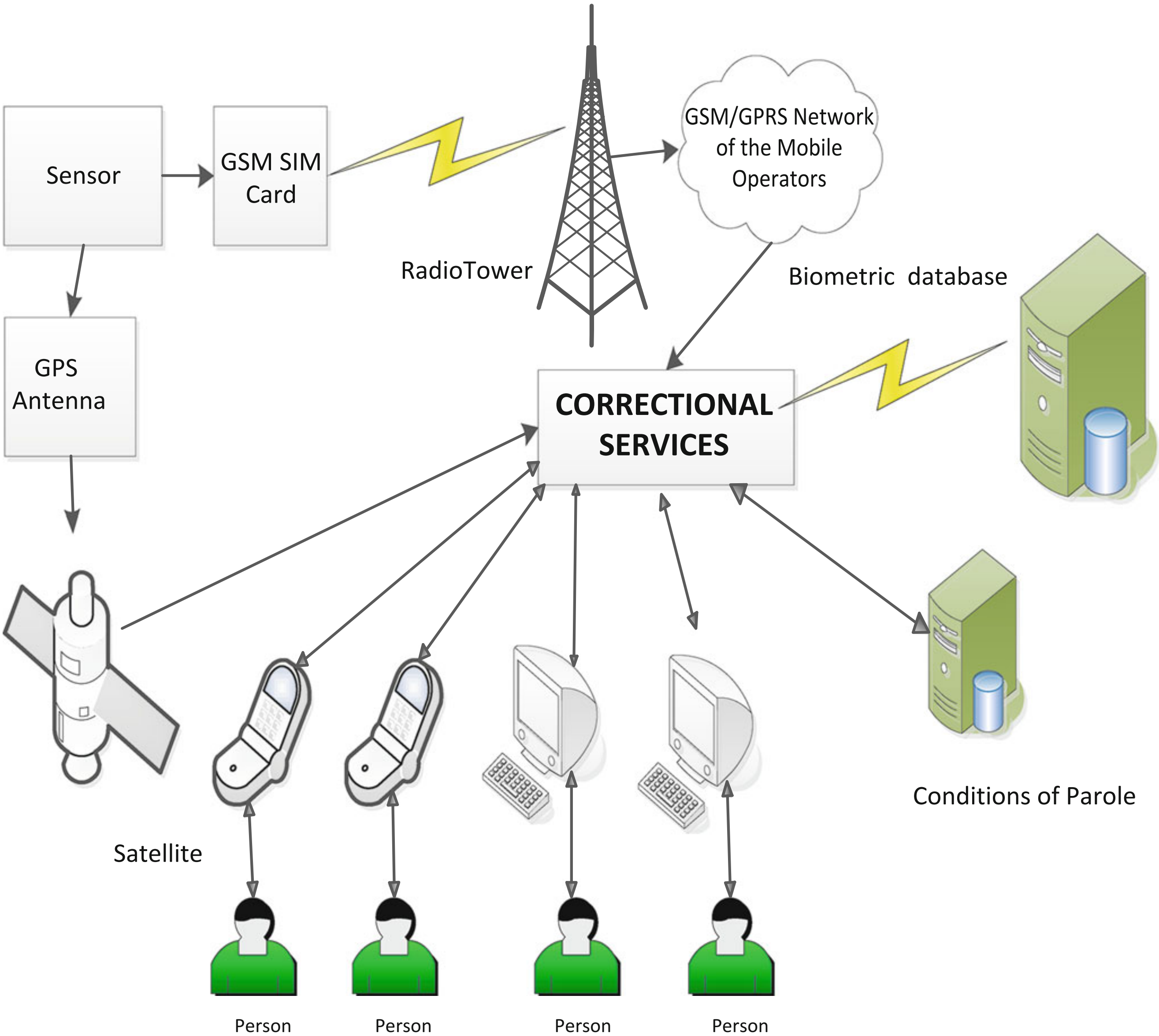

Fig. 2 Parolee monitoring

is not detachable. This tracking device has a GPS or GSM Sim Card (CHIPSET) for location of the parolee at any point in time. If the data is generated via the GSM CHIPSET it is routed by the mobile operator network to the Correctional Services Department. If it is GPS-enabled, it is routed via satellite to the Correctional Services Department. The Biometric database is connected to the Correctional Services Department systems via a virtual private network (VPN) for security of data. Also, the Correctional Services Department links to a database on the conditions of parole for each parolee of a particular ID tag. If the parole conditions (e.g. moving out of a zone of 5 km from residence) are violated, then and alarm is triggered on the Correctional Services System and the biometric database releases details of the individual to the monitoring officer for further action. This can be on a desktop computer or on a mobile phone. See Fig. 2 for details.

Conclusion

Although a number of IoT technologies identified in this research may sound familiar, the question of how far they are in use in South Africa still remains. The current national DNA database only holds profiles of certain but not all suspects and convicted criminals. Therefore there are still delays in the criminal justice system if a new offender cannot be identified quickly through DNA profiling. Fingerprint technology is the most common technology in use in

South Africa. The South African passport is not yet biometric although it contains certain security features. There is still room for improvement to catch up with the EU's biometric passport which is a more reliable form of authentication.

The IoT is about the integration of a varied range of traditional ICT technologies in applications for various domains. Therefore it offers a new research area for South Africa, with an enhanced potential towards improving community safety and crime prevention. ICTs have had an adoption in many sectors of the economy generally speaking, but IoT is an approach from a different angle. It is about utilising and combining the strengths of each of the various traditional technologies that are integrated into any one application. Lessons are also being drawn from other international players who are already developing and using IoT technologies.

The research does not cover all aspects of community safety and crime prevention as it is, but only those applications that could be identified. It could do with additions in areas such as performance indicators, crime threat analysis, public order maintenance, etc. to name but a few.

The research shows the potential applications of the IoT that can reduce, deter or prevent the occurrence of crime and ensure community safety. These applications fall under law enforcement, situational crime and social crime prevention. The final result of this document is to inform policy on the adoption of IoT in community safety and crime prevention. The study can also be used by developers of new IoT technologies as a base to building S.A. specific IoT technologies for crime prevention and community safety.

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Research Trends in Existing Technologies that are Building Blocks to the Internet of Things

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Abstract

The internet of things (IoT) is based on interfacing the digital and physical worlds and making the information generated as a result available via the internet. The challenge that IoT faces as a new research area, is in the identification of further research areas and the way forward. Therefore this paper is the culmination of a research to identify further research areas in the IoT and the relevance of IoT to South Africa. The research first conducted a review of 28 IoT European Union (EU) Framework projects available over the internet. From the reviews, the research extracted the technologies that the EU is conducting research on as building blocks to the IoT. Using an adaptation of the Graham Vickery and Sacha Wunsch-Vincent framework which analyses developments in ICT research and development, this research interviewed experts working with the identified technologies and came up with research trends in the various technologies that are building blocks to the IoT and its relevance to South Africa.

Keywords

Internet of things • Sensors • Embedded systems • Wireless broadband networks • Cloud computing • Mobile technologies • Interoperability

Introduction

The internet of things (IoT) is a group of 'things' sitting on the internet and the related applications that enable interoperability of these 'things' [9]. The 'thing' is a physical or digital object with added intelligence. The 'things' in the IoT publish, discover, describe and invoke services. IoT in itself is a unique approach to cater for low memory, low computational capacity and low power consumption devices.

IoT research is still in its infancy. As a result its definition and scope is still evolving. So are the research directions that it will take in the future. The challenge is that IoT is about integrating a varied range of technologies. To gain a deeper understanding of these technologies, one has to consult the experts in the various technologies. The IoT researcher, however, plays the role of an integrator at a horizontal level.

This paper identifies research trends in the technologies that are building blocks to the IoT and their relevance. The technologies identified included sensors and embedded systems, interoperability, security, communications and protocols, wireless broadband networks, cloud computing integration and mobile technologies.

Second section is on the problem statement. Third section is on sensors and embedded systems. Fourth section is on communications and protocols. Fifth section is on wireless broadband networks. Sixth section is on interoperability in the IoT. Seventh section is on cloud computing. Eighth section is on mobile technologies. Ninth section is on security in networks and the last section is the conclusion.

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_72,

Problem Statement

The IoT is about the integration and interoperability between "things". For researchers to be able to achieve integration and interoperability of these 'things' there is a need to understand the underlying building blocks to the IoT. These building blocks are existing technologies. The research questions that this paper answers are:

(a) *What are the research trends in technologies that are building blocks to the IoT research?*
(b) *What is the significance of these technologies to South Africa and the preparedness of South Africa to undertake research in these technologies?*

The research first conducted a review of 28 European Union (EU) Framework projects [3], since the EU researchers are the leaders in internet of things research. From the reviews, the research extracted the technologies that the EU is conducting research on as building blocks to the IoT. Using an adaptation of the Graham Vickery and Sacha Wunsch-Vincent framework [15] which analyses developments in ICT research and development, questions were posed to experts that work in the field to come up with research trends in the various technologies that are building blocks to the IoT. The framework answers questions on what is on the ground, who are the main role players in research in the technology, what are the future research areas, what are the research drivers, i.e. the needs at socio-economic level, what are the inhibitors to research on the technology, the relevance of the technology to South Africa and its impact. The technologies identified appear in Sections "Sensors and Embedded Systems" to "Conclusion".

Sensors and Embedded Systems

A sensor is a device that detects and responds to some type of input from the physical environment [16]. The input could be light, heat, motion, moisture, pressure or any of a number of environmental phenomena. The output is a signal that can be transmitted electronically over a network for reading or further processing. A sensor works as an embedded system, that is, it is a single purpose computer built into a larger system for the purposes of controlling and monitoring the system [4].

A sensor node, also known as a mote in North America, is a node in a wireless sensor network that is capable of performing some processing, gathering sensory information and communicating with other connected nodes in a network. The mote is a small, low-cost, low power computer. It monitors one or more sensors. It also connects to the outside world with a radio link. It transmits to a distance of 3–60 m. Power consumption, size and cost in motes are the barrier to transmission for longer distances. Motes can run on batteries or can tap into the power grid in certain applications. The battery life of a mote depends on the amount of data processed but varies between 2 and 3 years. If motes are dedicated to a specific function, their battery life lasts longer and energy is conserved. A number of varied sensors can be connected to a single mote, which gives it a non-specific function. Examples of motes for wireless sensor networks are TelosB, Micaz, TelosA, Telosky, STM32F4-Discovery, etc. Large numbers of motes can communicate with each other and form ad-hoc networks.

Future Research

There a number of dimensions that can be taken when conducting research sensors and embedded systems. Sensors won't work in an unsuitable environment. Therefore there is room to develop sensors/motes for the harsh environment such as dust, high temperatures and water logged places. Currently communication between any two sensors occurs via a central server and not directly. There is room therefore to enable direct communication between sensors by reprogramming them. Normally, each sensor is specialized, that is, it offers a specific function. There is an opportunity to integrate task-specific sensors towards a common functionality, in cases where several different parameters have to be measured. Alternatively addition of functionality to each sensor to be able to detect a number of various parameters would be the route. Since the energy supply of motes ideally comes from batteries, and battery life is limited and low capacity, there is an opportunity to move from battery-powered motes to energy-harvesting motes to avoid changing batteries frequently, and to conserve energy. Embedded systems protocols such as Zigbee and 802.15.4 enable integration of embedded systems with the internet and the integration of devices at the end. This means that there has to be standardization of these protocols for this integration to occur. Protocol standards are another research area. There is room for development of applications (middleware) for embedded systems. These applications enable interfacing with other embedded systems and the internet and integration with actuators, that is, it enables interoperability. Because of resource-constraints in these sensors (motes) intelligence is developed separately from the device. There is a need for development of algorithmic models for self-organising network design, routing around obstacles and tracking network management. The batteries that fire up sensors come in different forms for the various applications, i.e. made of different materials. For example in a health environment there is a restriction of chemicals/explosives that can be used to build the batteries. Research into battery technologies is a possibility.

Relevance to South Africa

The main South African organisations that are involved in sensor and embedded systems research are the South African Earth Observation network (SEON), the South African National Space Agency (SANSA), and the CSIR's units such as MSM, DPSS, Central Analytic Services (CAS), ESKOM. These are in areas of health monitoring, environmental monitoring, agriculture, factory automation and earth observation. The market is available in South Africa for products of research into sensors. There is infrastructure in place for such related research. However the inhibitors are that the competence is fragmented and the basic knowledge limited to a few. Also affecting research is policy issues and regulation. Funding for research is also limited.

Communications and Protocols

There are many ways to connect systems including wirelessly, via Ethernet cable or fiber cable. All these communication modes are of IEEE standards. IEEE protocol 802.1.A-B was the first wireless technology and was of a limited range. Now there is up to 802.1.G which is a higher frequency protocol. The higher the frequency of the protocol the shorter the distance it covers. 802.11.N has an even higher frequency of between 2.4 and 5 GHz and can be used to connect all devices in the home to access IPv6. The different IEEE standards are a security measure to protect connections between any two devices by restricting other protocols the device cannot recognise from accessing the device. IPv6 is the latest revision of Internet Protocol (IP), the communications protocol that provides an identification and location system for computers on networks and routes traffic across the internet. IPv6 was developed by the Engineering Task Force (IETF) to deal with the long anticipated problem of IPv4 address exhaustion. IPv4 was the first publicly used version of the Internet protocol. IPv4 included an addressing system that used numerical identifiers consisting of 32 bits while IPv6 addressing is 128 bits. Thus IPv4 provides an addressing capability of 2^{32} or approximately 4.3 billion addresses. IPv6 specifies a new packet format designed to minimize packet header processing by routers. Since the headers of IPv4 packets and IPv6 packets are different the two protocols are not interoperable.

The protocol stack is a set of network protocol layers that work together. The OSI Reference Model [5] that defines 7 protocol layers is called a stack. These layers are the application layer, presentation layer, session layer, transport layer, network layer, data link layer and the physical layer. The application layer defines the language and syntax that programs use to communicate with other programs, e.g. email, file transfer, client–server interactions. The presentation layer manages the way data are represented and encoded, e.g. American Standard Code for Information Interchange (ASCII) to Extended Binary Coded Decimal Interchange Code (EBCDIC), Binary Coded Decimal (BCD) to binary, etc. The session layer provides coordination of communications in an orderly manner, e.g. start-stop session. The transport layer is responsible for the validity and integrity of transmission, that is, it ensures the delivery of the entire file or message. The transport layer is like a door. Data has port numbers and headers to explain what it is, e.g., an IP address to the web browser. Each protocol has a specific port number. For example, Hypertext Transfer Protocol (HTTP) is port 80, Secure Shell (SSH) is port 22, File Transfer Protocol (FTP) is port 21. For security reasons a port number cannot be changed. The network layer establishes the route between the sender and the receiver to different local area networks (LANs) and wide area networks (WANs) based on the network address. The network layer is where IP addresses for the source and the destination are analysed for IP address authentication. If they cannot be authenticated, then access is denied. If the network layer sees its own IP and destination IP, it lets the data through to the transport layer, that is, TCP and UDP. The data link layer is responsible for node to node validity and integrity of transmission depending on station address. The link layer converts electric signals to data. The physical layer is responsible for passing bits onto and receiving them from the connecting medium. It is the electrical signals and cabling.

In the internet protocol stack [6], at the application level are Hypertext Transfer Protocol (HTTP), Remote Procedure Call (RPC), File Transfer Protocol (FTP), Simple Mail Transfer Protocol (SMTP), Advanced Message Queuing protocol (AMQP), Extensible Messaging and Presence Protocol (XMPP), Message Queue Telemetry Transport (MQTT), Real Time Streaming Protocol (RTSP) and Simple Object Access Protocol (SOAP), while in the machine protocol stack at the application layer is COAP (Constrained Application Protocol). COAP is a software protocol that targets small low power sensors, switches, valves and similar components that need to be controlled or supervised remotely through standard internet networks. COAP is designed to easily translate to HTTP for simplified integration with the web. The application protocol in the machine protocol stack should be able to handle information from the internet protocol stack for interoperability in IoT systems. All computers have TCP and UDP protocols in the transport layer. Transmission Control Protocol (TCP) is for transferring reliable data such as emails which have to get to a destination point. As a result it has 3 authentication points and takes longer. User Datagram Protocol (UDP) is not very reliable as it streams video data which can results in some packets being lost. In the internet protocol stack in the transport layer are IPv4 and IPv6 while in the machine protocol stack is 6LowPAN.

A routing protocol specifies how routers communicate with each other, disseminating information that enables them to select routes between any two nodes on a network [10]. Routing algorithms determine the specific choice of route. Although there are many types of routing protocols, three major classes are in widespread use on IP networks. Interior gateway routing is via link state routing protocols such as Open Shortest Path First (OSPF) and Intermediate System-to-Intermediate System protocol (ISIS). Interior gateway routing is via path vector or distance vector protocols such as Interior Gateway Routing Protocol (IGRP) and Extended Interior Gateway Routing Protocol (EIGRP). In Exterior gateway routing, the Border Gateway Protocol (BGP) is the routing protocol used on the internet for exchanging traffic between autonomous systems. An autonomous system is a network or group of networks under a common administration and with common routing policies. Routing protocols according to the OSI frameworks are layer management protocols for the network layer, regardless of their transport mechanism. ISIS runs on the data link layer. OSPF is encapsulated in IP but runs only on the IPv4 subnet while the IPv6 version runs on the link using only link-load addressing. IGRP and EIGRP are directly encapsulated in IP. EIGRP uses its own reliable transport mechanism while IGRP assumed an unreliable transport. Routing Information Protocol (RIP) runs over UDP while BGP runs over TCP. These routing protocols enable communication to occur with remote devices using various paths. ISIS is associated with larger networks while OSPF locates the shortest path that a packet can move.

Medium Access Control (MAC) [17] in a network card is a unique number which is used to communicate with other machines. Only manufacturers of the network devices can provide MAC. Companies purchase a range of MAC addresses in bulk, hence MAC addresses are unique to a device and are not duplicated. Companies also purchase only one IP address and the other IP addresses then become subnetworks of the original IP address purchased. Dynamic allocation is when computers in an organization do not have fixed IP address but are allocated IP addresses at any point in time when a transaction has to occur. Network Address Translation (NAT) translates private addresses in one network into a public address going into another network. In dual stacking, IPv6 and IPv4 addresses are running together in the same network. This results in increased overheads which in turn reduces efficiency of the network. The alternative to dual stacking is the IPv6 NAT which translates IPv6 into IPv4.

Future Research

There is room to develop one's own connection method and get allocated an IEEE number if the method is of world class standard. ISIS and OSPF use different algorithms. There is room to come up with new algorithms to learn the shortest path between any two routers. Research can be conducted on ways to reduce overheads so as to improve efficiency in dual stacking. UDP migration from TCP to avoid delays due to three-way communication is another route.

Relevance to South Africa

Due to an increase in the number of devices that are being connected to the internet, high-speed internet is a requirement. More mobile technology integration is a necessity into the internet. Wireless hotspots should be a prerequisite in every corner to reduce dependency on cell phone service providers. An increase in UDP communication is also a necessity.

Wireless Broadband Networks

Wireless broadband networking is a technology that provides high-speed wireless internet access or computer networking access over a wide area. 4G Long Term Evolution (4G-LTE), 4G-WiMAX, Universal Terrestrial Radio Access Network (U-TRAN), DigiMesh, General Packet Radio Service (GPRS), Bluetooth, are examples. Wireless broadband falls into local area and wide area categories. Wireless local area networks (WLANs) namely 802.11 Wi-Fi networks transmit at very high speeds but coverage area (hotspots) spans only a few metres. In contrast, the 3G/4G LTE wireless wide area networks (WWANs) from cellular carriers are slower but provide data services nationwide like they do with voice.

White space refers to parts of the radio spectrum that are not utilized all the time or in all geographic locations. Several regulators around the world are moving towards using unlicenced access to these frequencies, subject to the provision that licenced transmissions are not adversely affected. By allowing access to these white space frequencies, more effective and efficient use of radio spectrum is envisaged. Controlling access to white space spectrum involves use of cognitive radio techniques in which white space devices would sense their radio frequency environment and be able to automatically identify radio channels they could use without causing degradation to primary transmissions.

In wireless networks the problem of allocating transmission rights to subsets of networks users at each time and under different channel qualities is known as the scheduling problem. Transmissions tend to interfere with each other and also undergo impairments such as fading, attenuation, etc. Therefore scheduling mitigates that. Traffic analysis is the process of intercepting and examining messages in order to deduce information from patterns in the communications. It can be performed even when messages are encrypted and cannot be decrypted.

Future Research

Free space technologies where no spectrum is needed, e.g., to use sunlight to transmit data during the day (white light networking), and light from the moon during the night are one area of research. So is finding spectrum vacant spaces/holes in TV white spaces. So is the scheduling problem a potential research area. In the area of cognitive radios, research can be on scanning the environment and adapting parameters such as power, radios, antennae, CPU speed, memory allocations, embedded components and mobility. For energy-efficient networks, research on integrating renewable energy into these technologies is the route.

Relevance to South Africa

South Africa is currently under-served in broadband connectivity. E-government is an area that requires broadband access. Broadband is an accelerator of economic and social development according to the World Economic Forum. Broadband enables infrastructure for building the knowledge economy. The "last mile" of copper wires into homes and businesses is controlled by Telkom, limiting access by competitors to this infrastructure. South Africa's broadband policy is informed by the need to fast track the deployment of high-speed broadband infrastructure such as fibre-optic backbones and wireless and international connectivity. The role players are in the South African environment are state owned SenTech and Broadband Infraco.

Interoperability

Due to the large numbers of devices that connect to the internet of things, interoperability [7] becomes an important issue. Technical interoperability means that a signal can get from object A to object B. In other words, technical interoperability requires that objects be able to speak and be heard. Semantic interoperability means that object B can understand object A's message. Semantic operability requires that they speak the same language. Systemic interoperability refers to the ability of distinct IoTs to communicate with each other. It is another form of technical interoperability that deals with the arrangement of IoTs on a meta level. IETF is leading efforts to design international standards suitable for constrained environments including the internet of things, leading to a new protocol suite enabling interoperability between the regular internet and this emerging constrained environment. The working groups include 6LowPAN in the internet area, ROLL (Routing over Low Power and Lossy Networks) in the routing area and Constrained Restful environments (CoRE) in the application area. The other role players in interoperability are Internet Research Task Force (IRTF), IPSO Alliance, CISCO, Atmel and SICS. The common internet protocols are IP, TCP, DHPC, DNS, HTTP, TLS, HTML and XML. Dynamic Host Configuration Protocol (DHPC) is a network protocol used to configure devices that are connected to a network so they communicate on that network using IP. Transport Layer Security (TLS) is a protocol that ensures privacy between communication applications and their users on the network. Transmission Control Protocol (TCP) is one of the core protocols of the IP suite and provides reliable, ordered, error-checked delivery of a stream of octets between programs running on computers connected to a local area network (LAN), intranet or public internet. It resides at the transport layer. Domain Name System (DNS) is a hierarchical distributed naming system for computers, services or any resource connected to the internet or a private network. It associated information with domain names assigned to each of the participatory entities. HyperText Markup Language (HTML) is the main markup language for creating web pages and other information that can be deployed in a web browser. Hypertext Transfer Protocol (HTTP) is an application protocol for distributed, collaborative, hypermedia information systems. Extensible Markup Language (XML) is a markup language that defines asset of rules for encoding documents in a format that is both human-readable and machine readable.

Future Research

There is room for research in a new protocol suite enabling interoperability between the regular internet and this emerging constrained environment which is to be composed of a very wide range of smart objects with different communication technologies such as wireless sensor networks and wired control systems.

In the area of protocols there is room for investigating possible issues hindering wide adoption of the new protocols in crowded networks. The development of a transport protocol suitable for IoT and mappable to TCP so that a regular TCP connection can transparently flow into the constrained network and access the available services, by passing through a low-cost general purpose IoT gateway mapping TCP to a lightweight transport protocol is the route to go.

Relevance to South Africa

In the networking of data, there is an opportunity to network government data which has existed as autonomous and owned by various government departments separately. Integrated systems in any domain assist keep track of data so as to improve knowledge about the state of the world. Greater operability would mean that people can pick and choose their preferred technologies, leading to a greater competition in the market place. The trend nowadays is towards automation that is based on IoT principles for the various domains. Through capability enablement South Africa needs to empower the people involved with the right skills to be able to make the technology that is interoperable. This includes enabling data usage, application integration and application context. The main goal should be to describe the overall capability enabled at a particular Interoperability Readiness Level. It is relevant to South Africa and that is proven by the announcement that was made on the 14 June 2013 that the IEEE 1904.1TH Standard FOR SERVICE INTEROPERABILITY (SIEPON) was approved by the IEEE Standard Association (IEEE-SA) at the Standard Board meeting. It provides open, international, system-level specifications enabling multi-vendor, "plug-and-play" interoperability in EPON systems. The department of Communications, DST and DTI are driving initiatives of this kind.

The inhibitors to interoperability are at human and organizational level. Individual firms develop distinct and limited IoTs with internal technical and semantic interoperability. As IoTs spread international/governmental legal issues arise. Security issues are also escalated as a result of interoperability. For example, an attack targeting weaknesses in the system can shut the whole system down, install data collecting malware or control systems. On the issue of privacy, more interactions lead to more points of attack. More extensive communications lead to more data being collected, increasing more damage when the system is hacked.

One of the research drivers is the semantic operability, that is, the ability of devices to understand what the data they communicate means. This is about standardizing the protocol and data formats. RFID was standardized under ISO/IEC standard ISO 180000. The physical layer of most wireless systems is standardized under IEEE 802.15.4-2006 which lays out specifications for low power wireless personal area networks. There is usually a capability mismatch between traditional internet hosts and small devices due to the widely differing communication and processing bandwidths in different devices. This calls for interoperability at semantic level. The different internetworking protocol choices such as legacy IP versus IPv6 and simplified web protocols such as COAP/UDP instead of HTTP/TCP are key determinants of the level of interoperability in IoT systems. Where IPv4 and IPv6 exist in isolation from each other is the single stack, and where both exist in the same network it's the dual stack.

Cloud Computing

The cloud is a term for networked computers that distribute processing power, applications and large systems among machines [1]. It refers to a 'remote data centre', that is, computing is no longer on local computers but on centralized facilities operated by third party compute and storage facilities. Any IT outsourcing—network infrastructure, security, monitoring, remote hosting—is a form of cloud computing. Among the drivers that are encouraging more institutions to contemplate cloud services are budget pressures, calls for increased reliability of and access to IT systems, and the need for institutions to provide timely access to the latest IT functionality. Cloud computing services can be classified into three primary categories of software-as-a-service (SaaS), infrastructure-as-a-service (IaaS) and platform-as-a-service (PaaS). In SaaS an independent software vendor offers usage of applications as a subscription service delivered over a network. The advantage is that an application can be deployed without requiring expansion of the enterprise data centre infrastructure with additional servers, storage and networking resources, channels and applications. In IaaS, an organization can provide access to a large network of virtual servers that facilitate the development and testing of distributed applications. The goal of PaaS is to facilitate the deployment of applications without the cost and complexity of buying and managing underlying hardware and software layers.

Future Research

For the South African environment there is room for research into the public government cloud architecture. Currently the different government departments are the sole custodians of their data. This results in duplication of data. An integrated cloud platform would make the data available across all departments. Green cloud computing infrastructure that is environmentally-friendly offers another potential research direction. Hardware platforms and architectures with high energy-efficiency and low initial investment costs, security and productivity and reduces costs of signing in for services.

Digital cloud forensics is meant to gather evidence to support criminal cases in data that is associated with the cloud. Digital forensics is a branch of forensic science encompassing the recovery and investigation of material found in digital devices. The term digital forensics was originally used as a synonym for computer forensics but has expanded to cover investigation of all devices capable of storing digital data including the cloud platforms. This involves computer forensics, network forensics, forensic data analysis, cloud forensics and mobile device forensics.

Bring Your Own Device (BYOD) is an approach to enable access to enterprise resources from any device that is connected to the cloud without compromising the security of data. There is room to research on how this can be achieved, considering the IoT approach and the myriad of devices involved.

A business model describes the value proposition, market segment, and cost structure, position in the network of competitors, the competitive advantage and the infrastructure of a business entity. In the IoT approach to the cloud various business models result and these can be researched into.

Automated self-service provisioning is the ability to deploy an IT or telecommunications service by using predefined procedures that are carried out electronically without human intervention. Automating provisioning allows customers to set up and make changes to services themselves by using a web browser or other client interface to provide a more efficient and rapid response to business requests. Automated provisioning is a type of policy-based management, i.e. an administrative approach used to simplify the management of a given endeavor by establishing policies to deal with the situation.

Automating virtual machine migration is about allowing data centres to rebalance workloads across physical machines while applications on existing virtual machines continue to run. Simply moving an overloaded VM to a random underloaded physical machine can inadvertently overload the network. Research on decreasing network traffic during this migration is therefore an essential.

There is room for research in the area of legal implications of cloud computing and possible policy interventions. The number of trademark filings covering cloud computing brands, goods and services is increasing, increasing the risk of litigation. Data on the cloud can be stored in any country. The physical location raises the question of legal governance over the data. Organisations are legally prohibited from transferring personal information to countries that do not provide the same level of protection with respect to personal information.

Security is one of the most-often cited objections to cloud computing. A cloud-specific security issue is that of running arbitrary virtual machine images. This is only one aspect of making sure the right data is available to the user at the right time. The issues of authentication, authorization, privacy, integrity, data reliability and availability are to priority. When one participates in the cloud, they depend on third party to make decisions about data and platforms. When the internet goes down access to one's data is cut off. The security of a system is only as strong as the weakest user's set-up.

Relevance to South Africa

With the introduction of South Africa's National Health Insurance, collaboration in patient information and diagnosis is an essential, as a result of accessibility from anywhere. So is the government cloud platform for interoperability between government departments. The rural South Africa has limited IT infrastructure, hence hosting services externally not only lowers costs, but it also provides the scarce infrastructure. The key enabling institutions to a South African cloud platform are SITA which provides the cloud platform. The challenge though is manual capture of existing paper documents into the new cloud.

Mobile Technologies

Mobile technology is the technology used for cellular communications [12]. The future of computer technology rests in mobile computing with wireless networks. Mobile computing by way of tablet computers are becoming popular. Tablets are available on 3G and 4G networks. Many types of mobile operating systems are available on smartphones including Android, Blackberry OS, Web OS, iOS, Symbian, Windows Mobile Professional (touchscreen) and Windows Mobile standard (non-touch screen). Google Chrome is releasing an OS for mobiles where everything runs on the cloud. The phone is just a connection to the internet without any processing power. The next generation of smart phones is going to be context-aware, taking advantage of the growing availability of embedded physical sensors and data exchange abilities. One of the main features applying to this is that the phone will start keeping track of your personal data.

The trend in mobile technologies today is in the seamless migration of different technologies, that is, any mobile application should be able to run on a number of different mobile platforms without any modifications to it. The application should have the same interface irrespective of the device it is running on.

The main players in the mobile market in South Africa are Vodacom, MTN, Cell C, 8ta, Virgin mobile. The main role players in mobile research in South Africa are the

University of Capetown's Apple Lab and the Blackberry Lab at the University of Pretoria. The external role players are Samsung, Blackberry, Google and Apple.

Future Research

Current research is in the area of development of a mobile platform to which services can be added. In addition to this there is room for the development of mobile applications that offer a range of functionalities and are device-independent. There is room for developing web applications that run on mobile devices using software such as JQuery Mobile, ASP.Net, etc. In South Africa access to government services via mobile technologies currently is based on one way communication via SMS, MMS, etc. from the government departments to the citizens. Therefore there is room for research into two-way communications through mobile technologies. With mobility comes network congestion that requires a redesign of network connectivity. Japan has assigned IPv6 addresses in its networks to counter congestion and for reasons of scalability. Research opportunities are available in balance load scheduling algorithms on mobile platforms. With mobility also come issues of security, privacy, mobile governance and interoperability.

Relevance to South Africa

South Africa has its own set of problems that need solutions and some of these problems can be solved through mobile technologies. Health and mobile education in remote rural areas can be enhanced through mobile technologies. Mobile health information can be dispensed to remote areas using mobile technologies. Mobile diagnostic kits enable malaria detection on camera. In cases of blended learning where the internet provides education, mobile technologies could be handy. There are enough researchers in the mobile community to take mobile research forward. However, the degraded network power in remote regions can be an inhibitor to mobile adoption.

The need to establish quick communication, that is, roaming without a cable is one of the drivers of adoption of mobile technologies. Landline penetration is very low in South Africa due to inaccessibility of some areas and hazardous terrain. Therefore this drives the mobile market up since cell sites can be placed far and wide to cover a larger terrain. Unfortunately mobile costs are very high, with South Africa being the 6th highest in the world. Bringing the cost down would further up the impetus of adoption of mobile technologies. Cell phone service providers usually set up their own individual infrastructure. However a shared resource use by cell phone service providers would result in scalability of infrastructure. However congestion due to large traffic volumes results in calls being dropped at peak times, meaning there is a level of unreliability. There are many socio-economic problems in South Africa. Cellphone coverage is high in South Africa and offers the opportunity to bring services to the marginalized. When processing power is placed in the cloud and not on the handset, a web server processes the handset faster. In South Africa cellular access is via service providers predominantly and yet in more developed countries WiFi hotspots are available in every corner and funded by the government. There is also what is called location-based WiFi where according to the GPS the WiFi can be turned on and off. Nowadays cell phones are advanced in features for mobile support. The laptop is smaller and therefore moving towards mobility. These low-cost devices are also reason for the rise in cell phone banking.

Security

Well-designed security services can contribute to the reliability and robustness of a network's communications infrastructure and the protection of data sent over the network [11]. Any network communication medium has a protocol. The medium of communication is either wired or wireless. The protocol in a particular communication medium does not change, i.e., you do not have to install any particular software on it for the protocol to work.

Security threats on the networks can be both internal and external and each type of threat calls for different handling [8]. External security threats are as a result of unauthorized access. One of these is about connecting to the wireless node which is the entry point to a network and gaining access to network resources. The other one is installing a program either intentionally or unintentionally on the network, thus allowing unauthorized access to the network by outsiders. Vulnerabilities in the network such as buffer overrun pose a threat. An application is expected to reject junk, but in the case in which this is allowed, the code accepts unauthorized data such as a link to an external unauthentic connection for instance, or executes unauthorized code which threatens the system.

Any network-controlling entity has some maximum capacity in terms of memory and connections at a time, e.g., with a PABX one has to wait for an available line. Denial of service is about making a network inaccessible by making it busy through establishing too many connections and congesting it. The network administrator can easily resolve the issue if the threat is internal by identifying the IP address of the device that is congesting the network. On the other hand, if the attack is from an external source, the attacker may move from one IP address to the next to evade identification.

Device manufacturers provide APIs to developers so that their software can interface to the manufacturer's device. However the Android API comes from Google and not the manufacturer of the device on which the Android runs since Android is open source. Traditionally device manufacturers also come up with the operating system. Middleware enables heterogeneous devices to communicate. IP is normally built into devices. An open API at the top end of the system makes it easier to integrate devices rather than talk to each device separately. The middleware can link different vendor platforms. This results in security of data integrity when data is moved between devices.

Authentication is the process of identifying a user that can access a network resource. In a security system, authentication is distinct from authorization, which is the process of giving individuals access to system objects based on their identity. Authentication merely ensures that the user is who they claim they are, but says nothing about the access rights of the individual. Authentication asks the question, "Who or what are you?" Authorisation asks, "what are you allowed to do?". Accounting wants to know, "what did you do?". The existence of authentication, authorization and accounting is about enabling mobility and dynamic security as opposed to a network that must be statically configured to control access.

The main international players in network security are CISCO, MacAfee, Norton and JUNIPER.

Future Research

There is an opportunity to research on how to write antivirus software and firewalls that run on the same level. Anti-virus software runs on the operating systems such that when a virus is developed for the hardware (assembly) level it will act against the operating system. There is room to develop secure protocols. Protocols are defined by request for comment (RFC) that is a standard of IETF. Researchers normally put together a proposal on how to get a particular result and publish it as an RFC. Potential problems in protocols result from the implementation of RFC that may have been misinterpreted when code is written. There is research into understanding network security threats and their combinations by creating false-controlled scenarios. So is there an opportunity to develop security middleware.

Relevance to South Africa

In South Africa the key enabling institutions to network security are Electronic Communications Security (ECOMSEC), DPSS at the CSIR, FARITECH and NANOTECH for communications between embassies. The drivers to enabling network security are preserving data integrity, guarding against data loss, privacy of data and security of data. The need for an integrated network management system is also a key driver. The inhibitors are in the ownership of the data, institutional policies and government policies.

Conclusion

This research identified the research trends in technologies that are building blocks to the IoT and the relevance of these technologies to South Africa. These technologies vary from sensors and embedded systems, to interoperability, security, communications and protocols, wireless broadband networks, cloud computing, mobile technologies and socio-economic, legal, regulatory and governance issues. The information generated will assist guide the identification of the South African IoT landscape. It is also a measure of the research landscape in the basic IoT technologies from an international perspective. The technologies identified are what is already on the ground. The advantage is that the research now looks at South Africa specifically. To understand these technologies people with expertise had to be drawn from the different areas. Therefore IoT is a complex multidisciplinary area that needs multidisciplinary teams.

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Efficient Partitioning and Allocation of Data for Workload Queries

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Abstract

Our aim is to provide efficient partitioning and replication of data. We seek to accommodate a variety of transaction types (both short and long-running, read and write-oriented) to support workloads in cloud environments. We do so by introducing an approach that partitions and allocates small units of data, that we call micropartitions, to multiple database nodes. Only the necessary data is available to the workload in the form of micropartitions. Transactions are routed directly to the appropriate micropartitions.

First, we use agglomerative hierarchical clustering technique to group the workload queries based on data requirements. We represent each cluster with an abstract query definition. The abstract query definition is a query statement that represents the minimal data requirements that would satisfy all the queries that belong to a given cluster. A micropartition is realized by executing the abstract query.

We show that our abstract query definition is complete and minimal. Intuitively, completeness means that all queries of the corresponding cluster can be correctly answered using the micropartition generated from the abstract query. The minimality property means that no smaller partition of the data can satisfy all of the queries in the cluster.

Our empirical results show that our approach improves data access efficiency over standard partitioning of data.

Keywords

Cloud • Micropartition • Transaction • Data management

Introduction

There is a need to provide efficient data partitioning and allocation for services and service compositions in the context of both centralized and distributed systems [1–7]. Current web services solutions are based on full replication [8–11]. However this approach involves replica updates, which can be costly [12].

Our aim is to provide efficient partitioning and replication of data. We seek to accommodate a variety of transaction types (both short and long-running, read and write-oriented) to support workloads in cloud environments. We do so by introducing an approach that partitions and allocates small units of data, that we call micropartitions, to multiple database nodes. Only the necessary data is available to the workload in the form of micropartitions. Transactions are routed directly to the appropriate micropartitions.

We address the data partitioning and allocation problem for a service-oriented environment. The core idea is to design a system in the spirit of just-in-time inventory control where only the data required for current processes are available; it is a fragmentation and allocation technique based upon the concept of minimal data sets [13, 14]. We achieve this goal via a three-phased approach in which we outline an efficient data partitioning and allocation framework. In this

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_73,

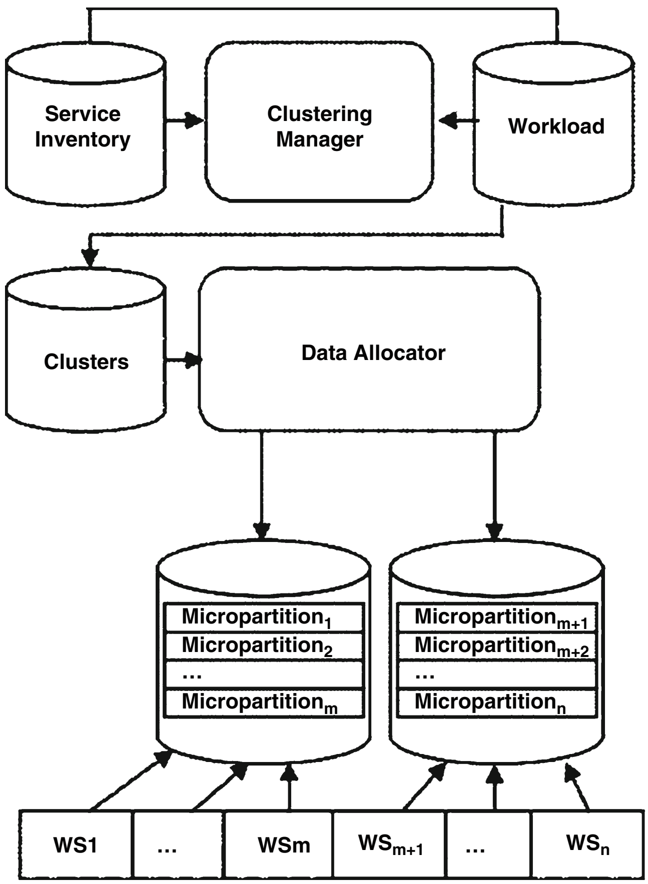

Fig. 1 Framework for Phase I—partitioning and allocation system

paper we present Phase I. In section "Conclusions and Future Work" we present the elements of Phases II and III (Fig. 1).

Phase I provides methods to identify data needs of atomic services and then groups services with similar data requirements. Abstract queries are created from these groupings. The abstract queries form the basis for micropartitions which are then allocated to database nodes. An atomic web service (WS) is a service that has only one query associated with it. In Phase I we assume that all services and nodes are in a central location, as in a cloud.

We show that our abstract query definition is complete and minimal. Intuitively, completeness means that all queries of the corresponding cluster can be correctly answered using the micropartition generated from the abstract query. The minimality property means that no smaller partition of the data can satisfy all of the queries in the cluster.

Our empirical results show that our approach improves data access efficiency over standard partitioning of data.

In section "Atomic Web Services Clustering and Allocation" we outline the clustering method for the atomic queries in a workload. In section "Abstract Query Description" we present the procedure for creating the abstract query definition. In section "Implementation Results" we describe our implementation, show and discuss results. In section "Conclusions and Future Work" we present are conclusions and describe Phase II and Phase III of our work.

Atomic Web Services Clustering and Allocation

In this section we group atomic WSs, based upon the similarity of their data requirements. For clustering as an optimization task, (1) an appropriate cost function must be developed, (2) a clustering method selected, (3) a relevant data abstraction applied to the resultant clusters and, (4) the clusters validated.

Atomic Web Service (WS)

We represent WS as a sequence of read and write operations on data items and a commit or an abort. We represent each WS as a relational algebra query, Q of the form $Q = \pi A \sigma C(D)$, where A is the set of attributes of D, and C is a conjunction of operations of the form ($a1$ op $a2$), where $a_i (i = 1, 2)$ are either attribute names or constants, and *op* is an arithmetic operator $=$, $<$, or $\leq$.

Clustering Cost Function

The cost function, for our clustering, includes two proximity measurements, v and h, each of which contributes to a final proximity equation, p. The measurement v is the vertical partitioning component of the clustering; h is the measure for horizontal partitioning. The first measurement, v, measures the dissimilarity between the attributes of two abstract queries, Q_i and Q_j. The second calculation, h, measures the dissimilarity of the conditions in Q_i and Q_j. We select the clusters with the smallest p value, to merge.

The first measurement, v, uses Jaccard distance to measure the dissimilarity between the attributes in Q_i and Q_j. Jaccard index measures the similarity of two sample sets; Jaccard distance is its complement, measuring the dissimilarity of two sample sets, and is calculated by subtracting the Jaccard index from 1. This measurement lends itself well to our problem because we can compare the attribute sets of the given query pairs, as we can also compare the sets of conditions. We seek to merge the two abstract queries having the least dissimilarity (lowest dissimilarity value) with respect to their attributes and conditions.

Dissimilarity of Query Attributes

For abstract queries Q_i and Q_j, v measures the dissimilarity between the respective attribute sets, A_i and A_j.

$$v = J^I(Q_l, Q_j) = \frac{A_{01} + A_{10}}{A_{01} + A_{10} + A_{11}}$$

where

A_{01} represents the number of attributes that are absent in Q_i and present in Q_j

A_{10} represents the number of attributes that are present in Q_i and absent in Q_j

A_{11} represents the number of attributes that are present in Q_i and present in Q_j

For example, given the following abstract queries

Q_i: π Discount,Last,Credit,Tax σ wId $< 2 \wedge$ dId $= ?$

Q_j: π Data,wId,dId

and their respective attribute sets

A_i: Discount,Last,Credit,Tax,wId,dId

A_j: Data,wId,dId

$$v = J^I(Q_l Q_j) = \frac{1+4}{1+4+2} = \frac{5}{7} = 0.71$$

In the abstract query section we prepared the selection conditions in the select statement from each query by (1) removing any conditions that contained user-defined attributes and (2) applying transitive closure to the statements in order to generate a complete set of conditions. We now calculate the second proximity measurement, h by evaluating the selection conditions in abstract queries Q_i and Q_j. This is a measurement of tuples returned, and, therefore, of horizontal partitioning.

We have developed a measurement based on the database schema and corresponding metadata and not on the actual database instances. For our initial analysis we apply the following simplifying conditions: (1) all attributes used in conditions have attribute domain restrictions that are defined in the database schema (2) data is evenly distributed in the database across the defined range of values for the attribute (3) conditions take the form conjunctions of A_i op c, where A_i is an attribute in the database, *op* is a standard comparison operator, $=, >, >=, <, <=, <>$, and c is a constant and that (4) we initially deal with integer data types. In Phase III we extend our model, removing these simplifications.

Dissimilarity of Query Conditions

For abstract queries Q_i and Q_j, h measures the dissimilarity between the respective condition ranges, R_i and R_j.

$$h = \frac{R_{01}+R_{10}}{R_{01}+R_{10}+R_{11}}$$

R_{01} represents the number of data values that do not satisfy Q_i and satisfy Q_j

R_{10} represents the number of values that satisfy Q_i and do not satisfy Q_j

R_{11} represents the number of values that satisfy Q_i and satisfy Q_j

For example, given the following abstract queries

Q_i: π Discount,Last,Credit,Tax σ wId < 2

Q_j: π Data,wId,dId σ wId ≤ 3

and their respective ranges, R_i and R_j, where R_i and R_j must contain integer values within the domain of wId, which is 1-15.

$$R_i : 1$$

$$R_j : 1,\ 2,\ 3$$

$$h = \frac{2}{3} = 0.67$$

Our final proximity equation incorporates both v and h.

Proximity Equation

Proximity equation, p, calculates the proximity value of two abstract queries, Q_i and Q_j.

$$p = w_v * v + w_h * h$$

where w_v and w_h are weights assigned to v and h. Initially, w_v and w_h are both 0.5.

Clustering Method

Queries for available services are exposed in the service inventory (or can be exposed in a workload trace). We also have a workload composed of WS and the first task is to gather all the associated exposed queries from the service inventory. It is helpful to create a dendrogram of the clusters when describing the processes of cluster creation. We will view each of the leaves of a dendrogram as the queries we have gathered that pertain to the current workload. This is level 0 of clusters in our tree. Each of these base queries will have similarity value 1.0 (dissimilarity 0.0) for both v and h.

Proximity measurement $p = (w_v * v + w_h * h)$ is calculated and stored, in a proximity matrix, for each query pair in the workload. We use the average linkage measurement to calculate p for all clusters in the hierarchy. We use a standard clustering algorithm to build the tree. Each level of the tree represents a newly-formed cluster (except for the first level which represents all the singleton clusters). We now label each level of the hierarchy with the similarity value for all the queries that participate in that cluster. The similarity values, from level 0 to the top-level, will be monotonically-decreasing from a starting value of 1.

Our next task is to select a suitable set of clusters from the hierarchy of clusters just created. Our objective function is to select a set of clusters so that the processing load is spread evenly amongst the clusters. We want to select clusters that are as balanced as possible with respect to this criterion. We call processing cost, *pc*, and will, initially, assign the data size of the micropartition to be generated from the cluster to *pc*. Processing statistics can be gathered as workload executes, allowing for reassessment of the *pc* values. Subsequently, *pc* values would be monitored so that splits or replicants of the clusters can be created as user demands increases. This is explored further in Phase III.

Once a processing cost, *pc*, is assigned to each cluster we use a variation on the gap method for selecting the level of the tree at which to select clusters. Large gaps between levels often indicate natural clusterings (these are points where adding one more cluster decreases the quality of the clustering significantly.). This is analogous to using the elbow method for selecting the number of clusters for k-means clustering. Therefore, cut the dendrogram at the gap where the difference between the *pl* levels is the large but where other the following constraints also apply. Given the number, *k*, which is the number of database nodes available for use.

1. We have identified a value as the relaxed capacity, *rc* for each node. This is the capacity for the initial load of the micropartitions. An individual micropartition cannot be any greater that the *rc* of a given node.
2. Set a reasonable number of micropartitions, close to a multiple of k. In this way, as the workload evolves, we manage smaller micropartitions (changing micropartitions as needed). Therefore, most micropartitions can remain online while others are removed, added, or updated. Our number of micropartitions, then, is $mk + n$ where m is an integer $m > 1$ and n is an integer $0 \geq n \geq k$.
3. We also select a number of micropartitions that keeps initial replication to a minimum. The more micropartitions we have the better out performance will be. However, replication of data becomes a factor. Replication is lowest at the top of the hierarchy and highest at the bottom. We must select a suitable number of micropartitions, not too few nor too many.

Clustering Data Abstraction

Each cluster in the hierarchy is tagged with an abstract query. The abstract query is a representation of the minimal data set that would satisfy the requirements of the queries that were used to build the cluster. The abstract query is used to create the data set that will be a micropartition. Other information stored with each cluster of the hierarchy is it's level *l* in the hierarchy, it's proximity value, *p*, a list *a* of the atomic queries associated with the cluster, and *pc*, the processing cost associated with each cluster.

Clustering Validity Analysis

Internal, external, and direct evaluation approaches are used to evaluate the quality of the clusters. We use direct evaluation as the method for external evaluation. We evaluate performance (throughput and response time) of a workload accessing micropartitions vs. performance of the workload against standard range partitioning techniques commonly used by database developers and administrators.

Micropartition Allocation

Once we have generated the micropartitions from the clusters we apply a standard bin-partitioning allocation algorithm assigning *rci* as a relaxed capacity value for each database node, *dbmsi* for $dbms = 1, \ldots, n$.

Abstract Query Description

The abstract query forms the basis for establishing data partitioning. The abstract query defines the data requirements for the partitions. The partition, generated from the abstract query, can service all the queries in the corresponding cluster. We call this type of partition a micropartition. Several micropartitions, collectively, address the data needs of the current workload.

Complex Web Service (CWS)

A Complex Web Service is a partial order of atomic web services. The WS composition is represented as a pair, $(\{WS_1, \ldots, WS_n\}, \leq)$ where, '$\leq$' is the partial order relation. We assume that queries that have similar data needs will be grouped into clusters.

In this section we define the abstract query and its propositions.

Abstract Query (WS)

Let Cl be a cluster of queries $Cl = \{Q_1, \ldots, Q_n\}$ where each query Q_j is of the form $Q_j = \pi_{Aj}\ \sigma_{Cj}\ (D)$, for $1 \leq j \leq n$ where D is a universal relation. We say that Q, denoted as $Q = \pi_A \sigma_C\ (D)$, is the abstract query representing Cl if the following hold:

For any database D

1. (Completeness) $Q_j\ (D) \subseteq Q(D)$ for all $1 \leq j \leq n$ and

2. (Minimality) $\nexists\, Q'(D) \subset Q(D)$ and $Q_j(D) \subseteq Q'(D)$ for all $1 \leq j \leq n$

Next, we explain the building of the projection and selection statements for an abstract query associated with a cluster.

Projection Statement, A, for Abstract Query Q

Let $Q = \pi_A \sigma_C\ (D)$ denote the abstract query for $Cl = \{Q_1 = \pi_{A_1}\sigma_{C_1}(D), \ldots, Q_n = \pi_{A_n}\sigma_{C_n}(D)\}$.

We create the projection statement, denoted as A, of Q as the set of all attributes that appear in A_j or Cj for all $1 \leq j \leq n$, that is $A = \{A_1 \cup \ldots \cup A_n \cup CA_1 \cup \ldots \cup CA_n\}$, where CA is the set of attribute names that appear in Cj for all $1 \leq j \leq n$.

Selection Statement, C, for Abstract Query Q

Let $Q = \pi_A \sigma_C\ (D)$ denote the abstract query for $Cl = \{Q_1 = \pi_{A_1}\sigma_{C_1}(D), \ldots, Q_n = \pi_{A_n}\sigma_{C_n}(D)\}$.

We create the selection statement C as follows such that

1. $Cj \Rightarrow C$ for all j = 1,. . .,n
2. There is no C'' such that $C \Rightarrow C'$ for all j = 1,. . .,n and $C' \Rightarrow C$ and $C \nRightarrow C'$

Intuitively, condition 1 ensures that any tuple that participates in the answer for C_j (j = 1,. . .,n) must also be in the answer for C. Condition 2 ensures that no more restrictive selection condition C' exists, such that the abstract query Q' conditioned on C' would contain the answers for all C_j (j = 1,. . .,n) but would not contain some of the answer returned for Q.

We developed a set of algorithms to compute the abstract query for a cluster of queries.

BuildAbstractQuery Algorithm BuildAbstractQuery calls BuildProjectionStatement in order to build the list of attributes, A, used in the abstract query selection statement. It also calls BuildSelectionStatement in order to build the abstract query's set of conditions, C, for it's selection statement. BuildAbstractQuery would then create the actual abstract query statement from the set of attributes, A, and the set of conditions C. Q is the final abstract query.

BuildProjectionStatement Algorithm Create the list of attributes, A, for the projection statement for the abstract query.

BuildSelectionStatement Algorithm Create the selection statement for the abstract query. Three activities are performed against the selection statements in each query in a cluster. First, all conditions that depend upon user-defined attributes are removed. A user-defined attribute takes an input value from the user which is then used as a variable in a condition. Therefore, all values for the user-defined attribute need to be made available to the service.

Second, transitive closure is applied to each selection statement in the cluster. We use a modified version of Warshall's algorithm to derive transitive closure for each selection statement. In Warshall's procedure one constructs a boolean table, populating the table with 1 s and 0 s. We create an initial adjacency matrix populating it with the inequalities found in the conditions of the selection statement.

The algorithm incrementally finds all possible paths, from one node (in this case an operand in a condition) to another (operand in a condition) in the matrix. Each time we find another path, we derive the proper inequality that would link the two operands together. That inequality is then placed in the matrix. We continue iterating through the matrix until no more paths are found.

Third, comparing pairs of selection statements, one selection statement is absorbed by another if there is full containment of one selection statement by the other; both selection statements are restructured into one if the pair of selection statements overlap. The final set of selection statements are combined via a logical $\vee$ to create the selection statement for the abstract query.

We show that the abstract query computed by the BuildAbstractQuery Algorithm is complete and minimal.

Proof Sketch: First, we show that $\{Q(D) \supseteq Q_j\ (D)$ for all j = 1,. . .,n. The schema of the answer generated by Q must contain all the attributes of the answer schemas of Q_j for all j = 1,. . .,n because A is the union of all the projection attributes of Q_j. Second, we need to show that every tuple, returned by $Q_j\ (D)$ must also be returned by Q. Note, that for every tuple t that is returned by Q_j, t must satisfy C_j; but then, because $C_j \Rightarrow C$, t must also satisfy Q and, therefore, must be in the answer set of Q. Third, we need to show that there is no Q' such that

$Q_j \subseteq Q$ where j = 1,. . .,n and

1. $Q' \subset Q$ and
2. $Q^I \nsupseteq Q$

We show this by contradiction. Assume that $Q^I\ (D) \subset Q(D)$ and t is a tuple such that $t \in Q(D)$ but $t \notin Q^I\ (D)$. Since $Q^I(D)$ is an abstract query, t must not be in the answer set of any query Q_j. But, then, t must satisfy C because it was returned by Q but t must, also, not satisfy C_j.

Let $C_j = c_1 \wedge \ldots \wedge ck$ be such that $c_k \notin C$ and t does not satisfy c_k. But then, the selection C of Q^I must contain c_k otherwise Q^I would have returned t.

The only possible reason that c_k does not appear in C is the result of generalizing C, the original selection condition. But, then, c_k should have been generalized for C as well, therefore t should have appeared in the answer set for Q^I and this is a contradiction because t was not in Q^I. □

Table 1 Summary metrics

	Throughput		Latency	
Method	Average (req/s)	Increase	Average (ms)	Decrease
Standard partitioning 1	29.78		113.15	
Standard partitioning 2	5.86		105.19	
Clusters (2)	93.25	+76 %	82.23	−22 %
Clusters (5)	110.26	+109 %	65.64	−38 %

Standard Partitioning 1—Create 2 Partitions from the Entire Database
Standard Partitioning 2—Create 2 Partitions from the Topmost Cluster

Implementation Results

In our partitioning implementation, we use the OLTP-Bench benchmarking system [15]. OLTP-Bench is an extensible, universal benchmarking infrastructure that centralizes several benchmarking systems. OLTP-Bench gives developers access to real and synthetic databases and a variety of workloads. The testbed is oriented toward OLTP and web-oriented workloads, making available,

1. Throughput: Average throughput sustained for a period of time.
2. Latency: Latency in microseconds while running at max throughput.
3. Warmup Time: Elapsed time going from a cold state to maximum sustained throughput.

We selected, from the OLTP-Bench infrastructure the TPC-C implementation found therein. TPC-C is an OLTP workload with a mixture of read and write intensive transactions that simulate an order-processing environment [16]. We modified the OLTP-Bench TPC-C benchmarking system, so that, instead of running 32 queries spread amongst five transactions, we remodeled the transactions so that we had fifteen transactions, each running 1 query.

For our purposes, we collected the throughput (requests/sec) and latency (ms) values every 5 s for 60 s for each workload run. We ran the TPC-C benchmark against four partitioned forms of a synthetically-generated TPC-C database. In all the four tests $k = 2$ is the number of nodes.

1. Standard range-partitioning of the entire database is a popular approach used by database managers. We created two partitions, one placed on each node. We placed information related to warehouses one through five in partition one and the information for warehouses six through ten into partition two.
2. Standard range-partitioning of the topmost cluster in the hierarchy (one cluster that contains the subset of data from the database that would minimally satisfy the workload). We again create two partitions, one placed on each node. We split the tuples, by warehouse, as evenly as possible amongst the two nodes.

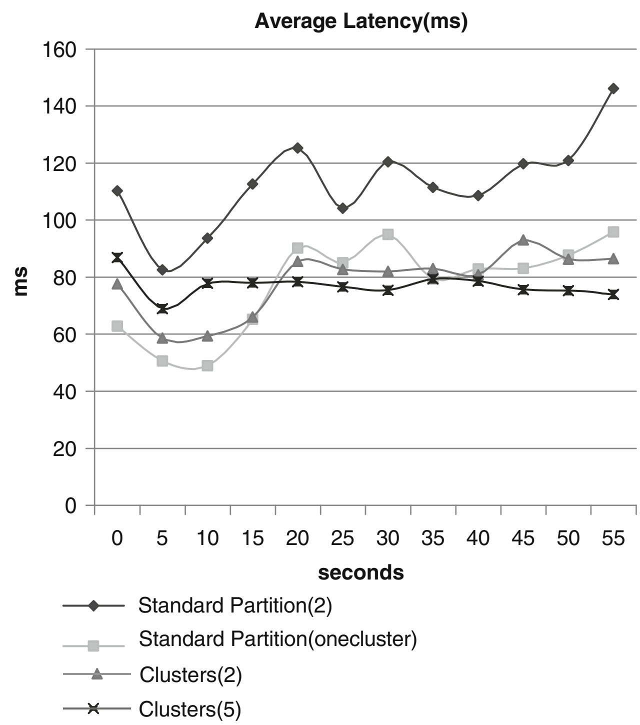

Fig. 2 Average latency

3. We slice the hierarchy at $k = 2$ clusters, taking clusters 28, 27. We create a micropartition for each cluster, placing one micropartition on each node.
4. We slice the hierarchy at $k = 5$ clusters, taking clusters 25, 24, 22, 21, 20. We create micropartitions for each of the five clusters and allocate the micropartitions to the two nodes in a balanced way.

Table 1 shows the results of our experiment. We see an increase of 76 % in throughput for a partitioning design using two clusters over standard partitioning using the same subset of data. We see an increase in throughput of 110 % for a five cluster design. The average latency for two cluster and five cluster improved over standard partitioning method by 22 % and 38 % respectively (Figs. 2 and 3).

It can be seen that average performance is much better when using the clustering method. However, if too few

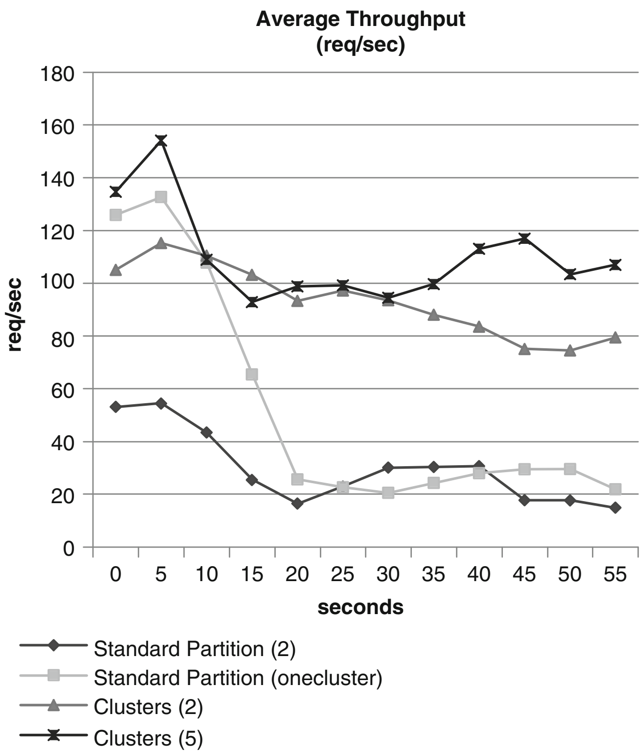

Fig. 3 Average throughput

clusters are selected we possibly see imbalanced performance where one partition gives superior performance to the transactions involved and the other partition gives poor performance. Therefore, selecting more clusters allows for the allocation of the generated micropartitions in such a way that there is more evenly-balanced performance among nodes.

There may be cases where queries that form a cluster have less significant vertical or horizontal partitioning. Performance, then, may be less than that of standard partitioning. Therefore, it would be worthwhile to apply range partitioning on those micropartitions that have slower response time and throughput. A beneficial area for future research would be how to combine clustering and standard partitioning methods to yield higher performance for a great variety of workload queries.

Conclusions and Future Work

In Phase I, the first part of our research, we have outlined a procedure for creating a set of partitions, called micropartitions, that can be distributed on database nodes to supply the data needs for a web service workload. Each of the transactions we have used in this phase have only one query. We developed an implementation that demonstrated that a set of micropartitions satisfied a workload and provided better performance than current standard partitioning techniques.

In our subsequent work we will extend our current approach. In Phase II we will extend the framework to include services that use multiple queries. In Phase II, we will also develop a system for handling replication of micropartitions.

Phase III will demonstrate the update process for the micropartitions, as the system workload evolves. Phase III will also extend the system for distributed environments.

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Toward the Automatic Construction of Strategic Plans Based on Ontologies

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Abstract

In this paper, the authors propose an approach toward the automatic construction of Strategic Plans based on Ontologies. Transnational corporations have units located in different geographical regions with a set of multiple nationalities. Aligning the targets and values to the global vision and mission of the company is an activity that needs constant update. However, it is possible that the strategists from different places will interpret the objectives differently and the alignment will not be close to the original. As a consequence, the image and profits of the organization could deteriorate. Verifying automatically the alignment of the goals of the organization to the global organization is important because it saves time, money, and the whole team could move in the same direction. This approach is based on ontologies where the knowledge and information about the plans are structured on class, concepts and data. It is also composed of a set of data retrieval and manipulation operations, which allow the approach itself to identify a set of patterns in the group of the strategic plans. Finally, the evaluation is carried out by performing a series of tests to determine the level of adherence to the proposed approach.

Keywords

Strategy development • Case studies in ontology • Application

Introduction

Any successful business is based on a strategic plan that organizes and involves everybody within the company to achieve common goals. Nevertheless, the language and the context of the strategists in different units of the organization are not always the same. If one of the strategists of an organization unit has a different goal to the mission and global vision, resources can be spent unnecessarily. It is important to have complete alignment with the vision, mission and objectives. That is why our research is focused on an approach that structures the knowledge of the plans based on ontologies and allows alignment between each of the organization's units. Also, we aim to verify that they are close to the original vision. This research has two important goals. The first is to explore the processes involved while executing the strategic plans. The second is to align the companies' previous strategic plans as other sources to be considered/included in the development process of new ones.

The main question addressed on this paper is the following:

Q1 Is it possible to align automatically a strategic plan to the organization based on the global organization vision?

The authors have identified two possible scenarios (S1, S2) to formulate the hypothesis (H1).

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DOI 10.1007/978-3-319-06773-5_74,

Table 1 Selected strategic management studies

Organizational structure and management	Strategy modeling	Strategy evaluation
Organizational configurations [1]	Diamond model [2]	Balance scorecard [3]
Office of strategy management [4]	Strategy maps [5]	
Strategic model management [6]	Analogical strategic reasoning [7]	

S1 The strategic plan is built from scratch. A major problem in this scenario is that the strategists do not have a guideline to start with the construction of a new strategic plan.

S2 Components of strategic plans from different companies are reused to form a new strategic plan. A vital problem in this scenario is that it is not possible to use components of different strategic plans because: a) they are difficult to access and b) the structure of their parts lacks portability.

H1 A system that builds and aligns strategic plans saves time and directs the user to a single path of the global organization.

This paper is structured as follows. Section "Related Work" gives an overview of the related work. Section "The Proposed Approach" describes the proposed approach and its components. Section "Experimental Details and Performance Results" describes the case studies of the process of strategy development, the research analysis, and experiments. Finally, the authors present their conclusions in section "Conclusion and Future Work".

Related Work

The previous research, which formed the basis of the present work, focused on two major areas: strategic management and ontologies.

Regarding strategic management studies, this can be grouped according to Organizational Structure and Management, Strategy modeling, and strategy evaluation as shown in Table 1.

Gruber [8] argues "an ontology is an explicit specification of a conceptualization". Research has demonstrated the practicality of using strategic management to structure strategy development through traditional techniques. Likewise, the use of ontologies has also proved the benefits of structuring and reusing previous knowledge in several projects as network ontologies [9] and knowledge management [10].

A considerable amount of literature has been published on strategic management studies and ontologies. However, the authors did not find studies on reusing and aligning automatically previous knowledge on strategic plans.

It is very typical to find organizations with unclear or diverse definitions of the concepts used in the strategic planning process. By using ontologies, it is possible to establish a systematic method of providing standard definitions with the same concepts, leading to the development and execution of a consistent strategy in the organization. The scope of our proposal covers the following:

A1 Main components of a strategic plan.

A2 Multipurpose companies that want to align with a new strategic plan.

A3 The activities of the main components of a strategic plan.

The Proposed Approach

The approach of construction is based on Strategic Plan (SP) ontology including the following elements: a set of strategic plans from different countries, an SP ontology, a reasoning model, and OWL interface, among others (as shown in Fig. 1).

An approach to representation of Companies' Strategic Plans based on ontologies retrieves concepts, relationships, data, information, and knowledge from a set of strategic plans.

The relationships among the different components of the approach are explained bellow. First, strategic plans are collected in digitalized documents from the World Wide Web such as different governmental offices and some firms, in several digital formats. They are then taken to the designers where the strategic plans are structured and modelled on SP ontology. Following this step, the strategic plans are structured into concepts and instances. In this process, the date and place of structuring are grab over them. In the next stage, the modelling of the strategic plans takes place in accordance with to the concepts, relations, and concrete domains they are addressed to. This is done by placing them in the appropriate reasoning model. Subsequently, the SP ontology is taken from the OWL interface and placed in the evaluation functions, which are then put onto a tester. While on this tester, the functions are directed to the appropriate secondary sorting section by means of naming conventions. In the secondary process, the ontology is assessed in the retrieval engine. Later, the ontology is accessed between the Java API and the interface application they are addressed to. Finally, they are placed in bags, which have the Strategic plan e-factory, and encoded to the strategic plans patterns.

The authors briefly describe each component proposed by the framework of the automatic construction of Strategic Plans based on the Ontologies approach as follows:

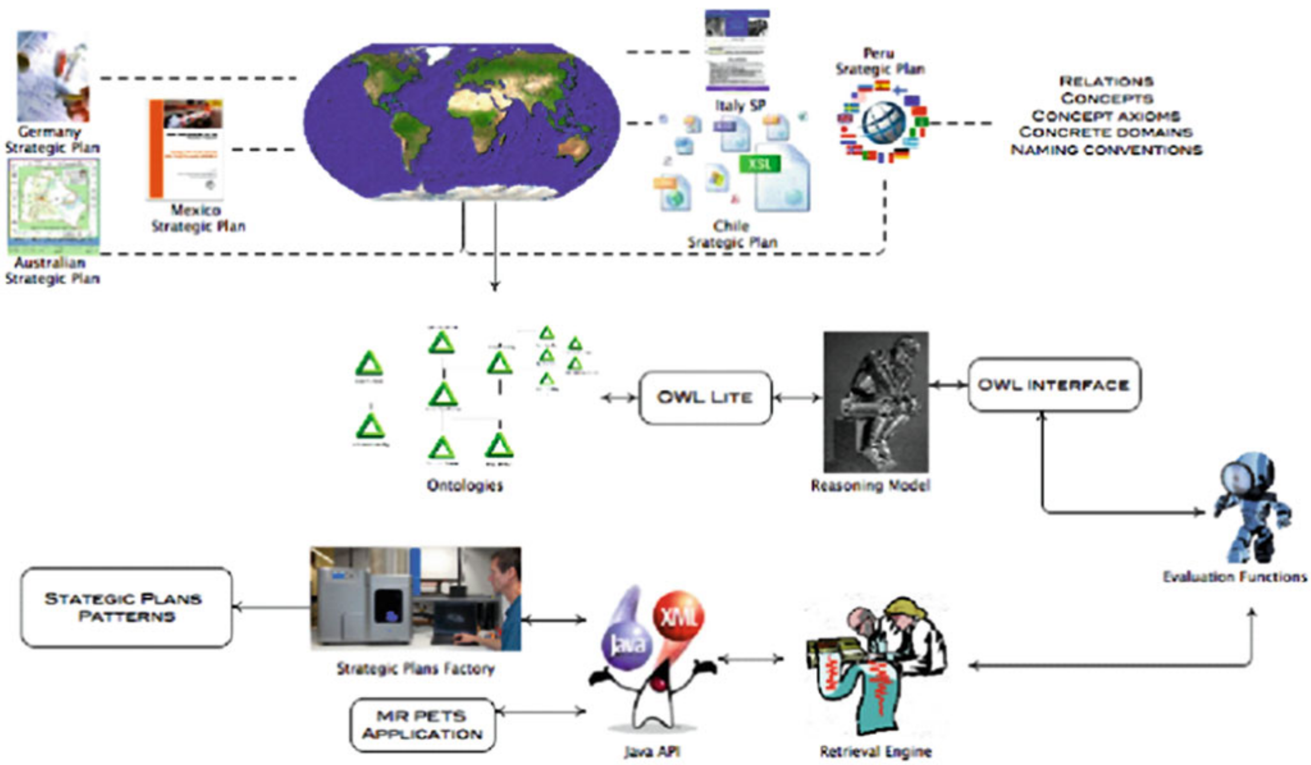


Fig. 1 The automatic construction of strategic plans based on ontologies approach

Strategic Plans

The set of strategic plans, the elements of the knowledge base of our approach, is taken from the World Wide Web (WWW). Using a crawler that starts with the seed of a set of companies, we are able to target where they are going by parsing the vision and mission of the document. Each strategic plan is carried out by a group of people mainly from governmental offices in different countries. All the plans are written in English, related to each other, and share a variety of data and structure. The relation representation that defines a strategic plan is in relations (2) and (3) described below. Relations (4) to (11) serve to consolidate relations (2) and (3).

$$\exists Enterprise.StrategicPlan. \tag{1}$$

$$\exists StartegicPlan.name.Constants, Analaysis, Evaluation. \tag{2}$$

$$StrategicPlan \equiv StrategicPlan \coprod Design \coprod Implementation. \tag{3}$$

$$Constants \equiv name \coprod author \coprod date \coprod distribution. \tag{4}$$

$$Constants \equiv Constants \coprod Members \coprod Sponsors. \tag{5}$$

$$Alaysis \equiv budget \coprod Goals \coprod Objectives \coprod Values \coprod SWAR. \tag{6}$$

$$Analysis \equiv Analysis \coprod Map \coprod Schedule \coprod SuccessFactors. \tag{7}$$

$$Analysis \equiv Analaysis \coprod ExpectingResults \coprod Bibliography. \tag{8}$$

$$Design \equiv Stratgegies \coprod Plans. \tag{9}$$

$$Implementation \equiv name \coprod Processes \coprod TargetResults. \tag{10}$$

$$\begin{aligned} Evaluation \equiv name \coprod Indicators \coprod Reviews \\ \coprod Status \coprod conclusion. \end{aligned} \tag{11}$$

The SP Ontology

One of the main characteristic of the SP ontology is language-independent.

Definition: the SP Ontology is a conceptual description based on the structure of a strategic plan as shown in

Eq. (12). The SP Ontology consists of four disjoint sets C, R, A, and ϒ where C means concept identifiers (13), R means relation identifiers (14 and 15), A means attribute identifiers (16), and ϒ means data types (17).

$$SP := (C, \leq c, R, \Upsilon R, \leq R, A, \Upsilon A; T) \tag{12}$$

The set C of concepts is:

$$C := \begin{cases} StrategicPlan,\ Goals,\ Weaknesses, \\ Aspirations,\ Strengths,\ Results, \\ Enterprises,\ Vision,\ Mission \end{cases} \tag{13}$$

The set R of relations is:

$$R := \begin{cases} strategicPlan\_of,\ author\_of,\ aspiration\_\ in, \\ strength\_in,\ result\_in,\ weaknes\_in \\ goal\_of,\ vision\_of,\ mission\_of. \end{cases} \tag{14}$$

where the relation hierarchy defines that StrategicPlan has the relation strength of that belongs to Strengths, has the relation goal in that belongs to Goals, following the same logic the rest of the relations are defined as shown in Eq. (15).

$$\begin{aligned}
&\Upsilon R(strategicPlan_of) = (StrategicPlan, Enterprises) \\
&\Upsilon R(author_of) = (Authors, StrategicPlan) \\
&\Upsilon R(aspiration_in) = (Aspirations,\ StrategicPlan) \\
&\Upsilon R(strength_in) = (Strengths,\ StrategicPlan) \\
&\Upsilon R(result_in) = (Results,\ StrategicPlan) \\
&\Upsilon R(weaknes_in) = (Weaknesses,\ StrategicPlan) \\
&\Upsilon R(goal_in) = (Goals,\ StrategicPlan) \\
&\Upsilon R(vision_in) = (Visions,\ StrategicPlan) \\
&\Upsilon R(mission_in) = (Misions,\ StrategicPlan)
\end{aligned} \tag{15}$$

The set A of attribute identifiers is:

$$A := \begin{cases} enterprise,\ strategicPlan,\ author,\ title \\ aspiration,\ strength,\ result,\ weakness \\ specificGoal,\ multinationalGoal, \\ visionGlobal,\ misionGlobal \end{cases} \tag{16}$$

The set _ of datatypes contains only one element a string as shown in Eq. (17).

$$T := (string) \tag{17}$$

The first axiom defines the concept specificGoal as equivalent to saying that there is a specificGoal which stands in a goal_in relation with the corresponding StrategicPlan, following the same logic the rest of the axioms are defined as shown in Eq. (18).

The reasoning model is a knowledge representation system that implements the calculation table for each expressive description logic. The system implements the description logic known as ALCQHIR+. The reasoning model handles constraints, role hierarchy, inverse roles, and the property of transitivity. It also includes algebraic reasoning.

$$\begin{gathered}
\forall x(specificGoal(x) \Leftrightarrow \exists y \wedge goal_in(x,y) \wedge StrategicPlan(y)) \\
\forall x(multinationalGoal(x) \Leftrightarrow \exists y \wedge goal_in(x,y) \wedge StrategicPlan(y)) \\
\forall x(visionGlobal(x) \Leftrightarrow \exists y \wedge vision_in(x,y) \wedge StrategicPlan(y)) \\
\forall x(misionGlobal(x) \Leftrightarrow \exists y \wedge mision\ in(x,y) \wedge StrategicPlan(y)) \\
\forall x(author(x) \Leftrightarrow \exists y \wedge author_of(x,y) \wedge StrategicPlan(y)) \\
\forall x(title(x) \Leftrightarrow \exists y \wedge title_of(x,y) \wedge StrategicPlan(y)) \\
\forall x(aspiration(x) \Leftrightarrow \exists y \wedge aspiration_in(x,y) \wedge StrategicPlan(y)) \\
\forall x(strength(x) \Leftrightarrow \exists y \wedge strength_in(x,y) \wedge StrategicPlan(y)) \\
\forall x(result(x) \Leftrightarrow \exists y \wedge result_in(x,y) \wedge StrategicPlan(y)) \\
\forall x(weakness(x) \Leftrightarrow \exists y \wedge weakness_in(x,y) \wedge StrategicPlan(y))
\end{gathered} \tag{18}$$

Retrieval engine recover instances and also finds all individuals in the population based on the search restrictions.

The retrieval engine recovers instances and also finds all individuals in the population based on the search restrictions. Strategic Plans e-Factory is a set of digital components built on strategic plans. Patterns of Strategic Plans constitute a means of codifying and transferring knowledge between projects and strategic plans. Mintzberg has indicated, in previous research, that design patterns are useful and have a probability concept to modelling. However, the authors did not find formal patterns of strategic plans in the literature. Therefore, after thorough analysis, the authors propose six patterns of strategic plan designs. These are: simple, basic, regular, composite, advanced, and expert.

Experimental Details and Performance Results

Each user case describes how the experiment interacts with the proposed approach to achieve a new strategic plan. The authors begin by describing the experiment and continue by explaining the user cases.

Experiment definition. The modelled problem for the two user cases UC1 and UC2 is described as follows: *designing a strategic plan for the domain of IT technology.*

User Case 1 (UC1). The experiment for the S1 was associated with user case 1 where a strategist is at Hewlett-Packard (HP). The automatic construction of Strategic Plans based on the Ontologies application supports software, in which the strategist observed a text box without any further data. Then, he modeled a strategic plan based on his experience at HP. For this case, the process for developing the strategic plan was concerned with an educational institution. It is important to note that the strategist expert works in the consultancy area of HP, and is not involved with education. However, he was able to translate his knowledge of strategy consulting projects in order to propose a strategy for a university. The steps required to develop the strategic plan in this case consisted of defining and revising in depth the vision and mission of the university, the creation of a benchmarking exercise, the identification of core and related educational competencies that contribute to their success in meeting stakeholders' expectations, an assessment of the current situation including opportunities and threats, the identification of alternative strategies to compete for the target market, and the selection of the strategies contributing the most to the mission of the organization.

User Case 2 (UC2) was associated with S2 where a strategist is at UDLAP (University of the Americas). The strategist had a bag from parts of the different strategic plans, and could select the listed components of the automatic construction of Strategic Plans based on Ontologies approach in order to create the Strategic Plan.

The experimental results are carried out in two ways: a) through a survey and b) by carrying out a strategic plan resulting from the automatic construction of Strategic Plans based on the Ontologies approach containing: 1) the metrics of the experiment and 2) the matched SP ontology between the automatic construction of Strategic Plans based on Ontologies approach and the resulting strategic plan.

The following section is a detailed description of the experimental results. The first part focuses on the results obtained while carrying out a strategic plan resulting from the automatic construction of Strategic Plans based on the Ontologies approach.

Strategic Plan Resulting from the Automatic Construction of Strategic Plans Based on the Ontologies Approach

As mentioned previously, the strategic plan resulting from the automatic construction of Strategic Plans based on the Ontologies approach is carried out in two stages: 1) the metrics of the experiment and 2) the matched SP ontology between the automatic construction of Strategic Plans based on the Ontologies approach and the resulting strategic plan.

1) *The metrics of the experiment:* In the first case (UC1), the main findings can be summarized as follows: the authors observed that the strategist understood correctly the design of a strategic plan for educational goals—although he is not an expert in this area—. The strategist is a senior consultant of a multinational company, whose levels of abstraction, experience and knowledge are high since he has reused a strategic plan and eight other components as input to complete the task. The strategic plans reused were of two companies. By using all this information he was able to build the new strategic plan.

   In the second case (UC2), the strategist's level of experience is on the middle level. He reused a detailed description of data based on different formats taken from the existing strategic plans of three companies. As a result, the strategist was able to build the new strategic plan by reusing components and keeping low the cost of its design. Therefore, we can infer from such findings that the modelling concept of reusing existing plans was helpful in developing a strategic plan for a particular organization, and could be used to determine the master plan in other environments.

2) *The matched SP ontology:* Fig. 2 shows some of the screenshots of the system for the automatic construction of Strategic Plans based on the Ontologies approach for each user case. It is indicative of how much adherence there is in each experiment: not at all, little, average, much or absolutely.

Conclusion and Future Work

From this work, there is a contribution to the enterprises, since SP ontology can be used to: a) share, extend, structure, and organizate knowledge as they are key features of the strategy development process in a globally world. b) represent the data, the information, and the knowledge of their strategic plans. c) access the design patterns for a set of strategic plans. d) merge, reuse, extend, and adapt the knowledge of the companies' strategic plans due to the flexibility of the proposed approach.

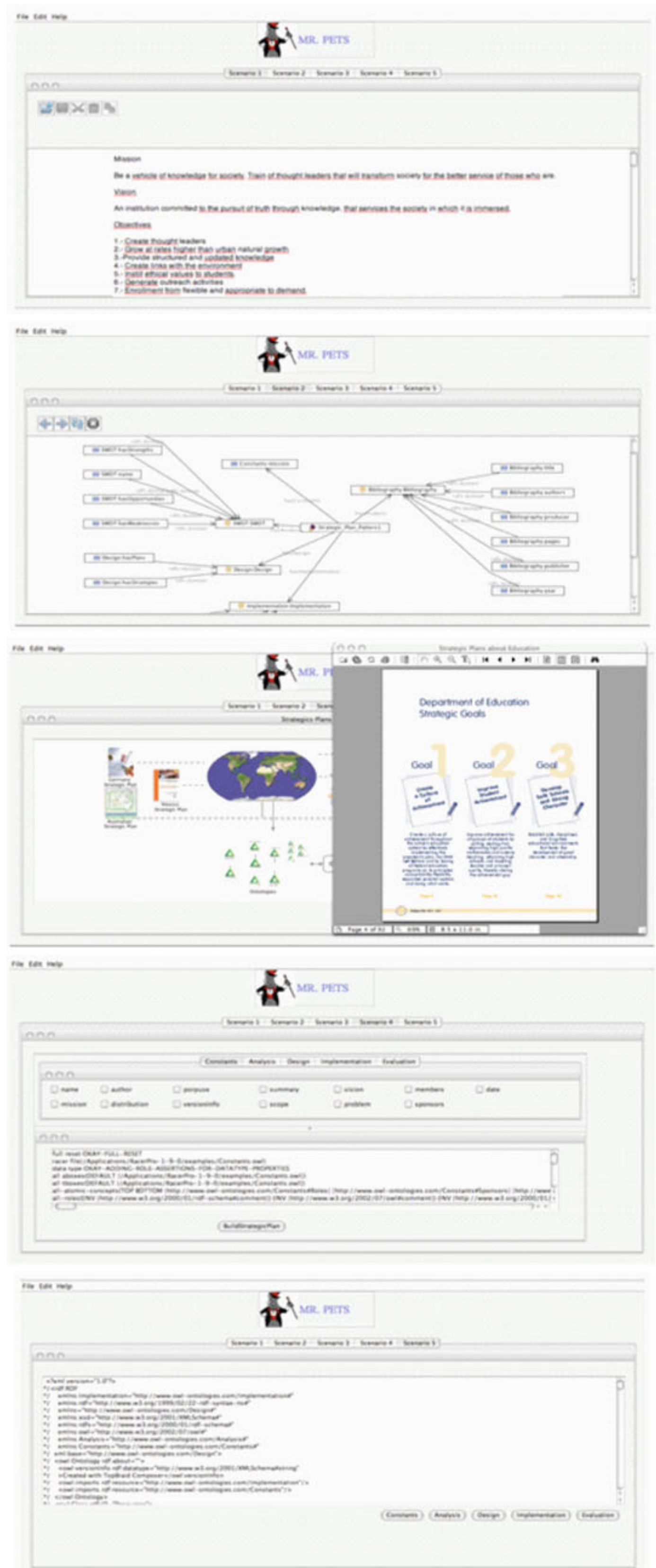
Furthermore, one of the most striking observations from the data has been that the current strategic plans do not have a uniform structure.

In the first user case, the strategist reuses previous knowledge and strategic plans to build a new strategic plan from scratch. It is also possible to observe that the development of a new SP (Strategic Plan) is agile and of high quality.

In the second user case, the conclusion is that the strategist will find it easy to create a new strategic plan by using different parts of strategic plans. Furthermore, the time required to create the strategic plan was very short, resulting in a high quality strategic plan. In this scenario, it is interesting to observe how important is the reuse of another strategic plan to make the design process more efficient.

The significance of the results is that the processes and outcomes of strategy development in a globalizated world are better accomplished by using the knowledge available on the net. This greatly benefits the industry because such knowledge is of freely available. In addition, the industry can structure its own resources for strategy development by using the automatic construction of Strategic Plans based on the Ontologies approach, since it evolves and responds to share, extend, structure, and build the strategic plans digitized in several formats and then aligns their vision and mission globally.

Fig. 2 The screenshots of the system for the automatic construction of strategic plans based on ontologies approach



One of the contributions of this research is that we found a lack of structure in most of the strategic plans, which triggers a simple recommendation, that is, to streamline and simplify the strategic planning development methodologies.

Finally, further work should be done to label and build a set of existing strategic plans as input to the proposed existing knowledge base.

Acknowledgements We are grateful to the Sciences Research Council (CONACYT) for funding this research project.

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E-Learning Environments: Actor Network Theoretic Inspirations into Localized Discovery

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Abstract

Virtual delivery of learning is widespread among many educational institutions which deploy learning management systems for this purpose. However, these systems yet fail to deliver similar experience with face-to-face learning environments despite added benefits they poses compared to face-to-face learning. This article study conceptual ideas, in particular actor-network theory, which can be used to design virtual learning environments.

Keywords

E-Learning • Actor network theory • Human computer interaction • Localized discovery

Introduction

From a broader point of view, in order to understand and study technology within social contexts, we can look at well-established critical apparatus such as socio-technical systems thinking [1–3] and actor-network theory (Latour, Law, Callon and Akrich). We look at these as they apply to various information artefacts, systems, and infrastructures and we will investigate useful concepts and theories that enable us to study technology artefacts such as discussion forums in learning systems both course-grained and fine-grained point of view. Typically such artefacts are derived from abstract plans and policies in order to facilitate such plans, in this case teaching and learning plans and policies. From the point of view of learning environments, we view as a plan, a layered out structure or a process, where participants are required to undertake in order to accomplish educational objectives. It appears that these technology artefacts in general, designed using traditional systems thinking point of view does not productively integrate into imagination of the users of such systems in particular at macro scale. Why the study of interaction is crucial for the successful delivery of knowledge. Think of a student going straight to the exam as opposed to going through the lectures, tutorials and thus following typical rituals related to studying. The primary difference is the interaction with various actors that participate in the process. The objective of this paper is to analysis the course-grained and fine-grained mechanics of the process of knowledge acquisition, and thereby application within learning environments. We review two such theories relevant to technological artefacts in learning environments. The first, situated actions, originate from human computer interaction research while the second, actor-network theory, originates from science and technology studies in sociology. Our investigation is in part cantered on the mechanics of interaction. We need an apparatus that is sufficiently rich so that we can understand, and thereby model, the socio technical aspects of learning. Actor-network theory (ANT) provides this apparatus. We will argue that learning environments can be modelled as heterogeneous networks. Actor-network theory is a vehicle flexible with granularity so that we can zoom in and out of actors or nodes, human or non-human in such networks. Within the concepts of situated actions and actor-network theory, we will enlighten the role of localized discovery in learning environments. In addition, we identify core functionalities of software artefacts of online (virtual) learning environments can be founded on social theory. We further argue that the performance limits of the

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_75,

participants in online learning environments must be reachable with embedded software artefacts despite the virtual nature of such systems. Overall objective of this research is, for a given cohort and with given policies and plans, what are the verifiable core features or technologies that can achieve performance limits in terms of achieving educational objectives.

Situated Actions and Localized Discovery

There are two views that are relevant to intelligence and resulting actions [4]; European: the plan is derived from Universal Principles, and Trukese: the objective is clear, but the course is contingent on the circumstances. The European view results from abstract analytical thinking while Trukese view favours wisdom and experience. These two views are used by [5] to build the situated actions theory of human computer interaction. Suchman explains situated actions as follows:

> the course of action depends in essential ways upon the action's circumstances. Rather than attempting to abstract action from its circumstances and reconstruct it as a rational plan, the approach is to study how people use their circumstances to achieve intelligent action. Rather than build a theory of action out of a theory of plans, the aim is to investigate how people produce and find evidence for plans in the course of situated action.

Suchman [5] claims that "if we look at the world commonsensically, the environment of our actions is a succession of situations that we 'walk in to,' and to which we respond. Communication, correspondingly, is an exchange of information, based on our observations, about the facts of the situations in which we find ourselves." Suchman also quote the arguments by George Herbert Mead (regarded as one of the founders of social psychology):

> Human group life was the essential condition for the emergence of consciousness, the mind, a world of objects, human beings as organisms possessing selves, and human conduct in the form of constructed acts.

Within the context of learning environments, both face-to-face and virtual, situated action and social group life implies that localized discovery needed to take place, i.e. discovery is situated. The object of this localized discovery is situated actors, human or non-human. Localized discovery could be coincidental, for example human actors in face-to-face learning environments, or objective driven. The idea of discovery in the context of learning is related to the active learning rather at a more course-grained level [13].

Despite that the idea of situated actors rely on situational experiences, if software artefacts are to use it within learning environments, it needed in general derived from plans since learning environments are typically abstracted resulting in plans, on the other hand must be situated within societal experiences. Thus we require a theory that is consistent with abstract analytical thinking on a macro scale as well as societal experiences which involve uncertainties on a micro scale. We look toward actor-network theory in order to provide this consistent theory, and in particular to understand the actions that are required and its structure.

Actor-Network Theory and Learning Environments

The simplistic view of actor-network is that all influencing factors must be considered, resulting in a network of both human and non-human actors, in order to understand effects thus resulting in detail and precision. ANT theory aims to uncover detailed descriptions of concrete mechanisms at work that glue such networks together. In order to understand learning through the actor-network theory glasses we take the view of learning as re-assembling the knowledge in every human actor who participates in the network assemblage.

The two concepts of actor network theory that are relevant for the design of information systems are: inscription and translation. While inscriptions have many forms, it conceptualises the patterns of usage of technical artefacts:

> An inscription is the result of the translation of ones interest into material form [6].

The actors have their own interests which are in constant tension within the more decentralized network while translation plays the role of acquiring stability by re-interpreting own interest resulting in alignment of interests of actors. Thus translation is viewed as a dynamic negotiation process which acts to bring stability to the network.

In summary actor-network theory provide us with a ground-up apparatus to describe and analysis information systems within context. It is often recognized that information systems-design and their use must be situated and contextual [5]. Actor-Network Theory can be used to understand and thus analysis the context of information systems in order to identify concrete mechanisms at work within such networks.

Face-to-Face Learning Environments

Let's take the observatory stance of face-to-face learning environment having large number of participants. Human participants such as students, instructors, coordinators, technicians, administrative staff, librarians and non-human actors such as texts, learning resources, computers, library etc. together forms an actor network in a face-to-face learning environment.

Looking at a face-to-face learning environment, the participants (primarily students) engage in communication within loosely structured clusters of participants which in turn loosely connected to form the network of human and non-human participants. Within these clusters, heterogeneous models or concepts are formed by each individual in order to understand and engage in the subject matter. These models undergo translation and alignment as they engage in communication with other participants they associate with and other non-human content and tools they use such as texts, web, computers, etc. Thus despite of the presence of structured delivery of content and assessment, a loosely structured process of concept building take place. In such face-to-face environments, discovery of other actors (i.e., network formation) is rather localised and contribute to the formation of clusters.

This localized discovery seems crucial in actor networks for both inscription as well as translations as is evident by the writings of Akrich ([7], p. 208) in the context of technology innovation:

> Designers thus define actors with specific tastes, competencies, motives, aspirations, political prejudices, and the rest, and they assume that morality, technology, science, and economy will evolve in particular ways. A large part of the work of innovators is that of inscribing this vision of (or prediction about) the world in the technical content of the new object.(. . .) The technical realization of the innovators beliefs about the relationship between an object and its surrounding actors is thus an attempt to predetermine the settings that users are asked to imagine (. . .).

Thus localized discovery of both human and non-human participants is crucial to the process of translation and inscription. The success of localized discovery of actors, then the translation process of alignment of human actors interests, knowledge, etc. with stipulated objectives of subject matter followed by inscription of behavioural patterns and iteration of this over time leads to the success of the learning environment.

On-Line Learning Environments

One can view on-line learning environment as an innovation artefact of an actor network of face-to-face environment. The entire on-line learning environment can be viewed as a macroscopic actor in this study. Within on-line virtual learning environments, discussion forums take the place of this loosely coupled communication network of concept building that exist in face-to-face learning environments. However, in this translation, discussion forums loose certain aspects of face-to-face setup while add other features due to its virtual nature. Localized discovery is replaced by global network wide discovery which has its advantages as well as disadvantages. Translation and alignment is a messy process due to global presence. Certain opinions and concepts otherwise build in a face-to-face network may not get build due to fear of global presence etc. Communication complexity may get to unmanageable level thus reducing the productivity of actors.

Implications and Suggestions for On-Line Environments

With respect to online-learning environments, computers provide both content and context for communication among various actors, typically human and could be non-human as well. Thus the software artefacts that we provide as part of learning environments, in particular on-line environments, must be embedded with functionality and flexibility so that they sufficiently glue the participants so that the resulting network evolve towards their objectives subject to the constraint that complexity (primarily communication) that can result in is manageable for the participants.

We argue that the localized discovery is fundamental at fine-grained level in order to accomplish the learning objectives and thus learning environments. The idea of localized discovery is perhaps justified from the point of view of human cognitive limits. What we observe is that localized discovery is coincidental and undergoes a selection process in order to align and converge towards individual interests. This transformation process is illustrated in Fig. 1.

In a pure virtual environment, confidentiality can be achieved by global observation and randomization/choice at the beginning. The selection process and confidentiality can be accomplished by access control mechanisms. The overall localized discovery process could be achieved by collaboration, randomization and access control resulting in implied adaptation of macro plans. The following table identifies mappings between actor-network theory concepts to software artefacts:

Concept	Artefacts
Inscription	Collaboration software
Translation	Collaboration software, version control
Localized discovery	Randomization, Access control software
Privacy	Interface and view adaptation, Access control software

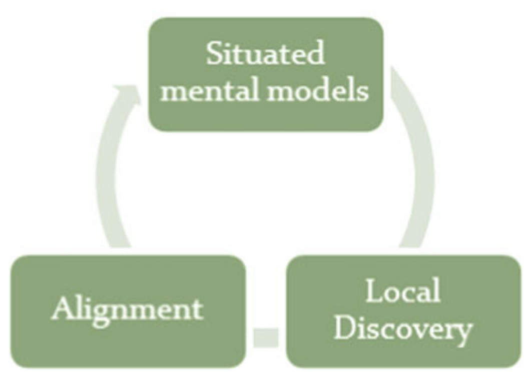

Fig. 1 Localized discovery

If a given virtual environment is equipped sufficiently with software artefacts having above features, are we achieving the societal performance limits of that cohort in terms of educational objectives? Indeed information technology has a capacity to improve performance by replacing actions that are naturally tedious for human beings such as localized discovery of non-human actors. This could be in the form of zooming into contents that are situational for example. However, in the absence of core features of software artefacts that are founded on social theories and human computer interaction, it is unlikely that technological artefacts can bring a given cohort towards performance limits in terms of educational objectives, however advanced they are.

Conclusion and Further Research

This paper argued that actor-network theory in science and technology studies and situated actions research in human computer interaction can be used in order to base design decisions of E-learning environments. In particular, the role of localized discovery is identified as a very important process in learning with E-learning environments. Further research of this work will involve design of various tools for discussion forums and content presentation and adaptation using the ideas of actor-network theory and situated actions of HCI research.

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Educational Tools: A Review of Interfaces of Mobile-Augmented Reality (mAR) Applications

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Abstract

This paper reviews the types of mobile Augmented Reality (mAR) interface being utilized in various applications such as education, advertisement, production, tourism and other applications. The objective of this paper is to examine the limitations on the types of mAR when they are used in higher education in terms of interaction between learning, teaching and instructional design. Based on the review, it can be concluded that there is an insufficient mAR interface being used in viewing the augmented images for classroom learning. For example, there are only two interfaces found that is being applied in the current mAR education applications. A comparative review presented in this paper suggests the appropriate mAR interface that can be implemented in education that could possibly enhance the learning outcomes.

Keywords

Educational tools • Mobile augmented reality • Learning • Framework

Introduction

Augmented Reality (AR) functions are an emerging technology in many mobile applications recently. Various applications have been created for the smartphones to offer more convenience and innovative ideas [1, 2]. However, far too little attention has been paid to the interface of AR in mobile applications.

This paper reviews the AR interface used in mobile applications across various fields such as advertisement, storyboarding, tourism and education; both in indoor and outdoor settings. The focus of the paper is to understand the requirements of AR used in higher education. One possible hypothesis, yet to be proven, is that mobile AR (mAR) is a technology that could help to deliver messages successfully. A real surrounding with a superimposed image overlaid on top of the real surrounding not only allows us to learn about the environment but also assists us with the tool to construe it. The paper begins by examining the interfaces and examples in mAR used specifically for higher education, and some conclusions are provided at the end.

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mAR Interface

Review Stage

An interface should have intuitive interactive characteristics between the user and the mAR system. There are four types of mAR interfaces. They include tangible interface, collaborative interface, hybrid interface and multimodal interface.

T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_76,

Hurst and Wezel [3] explained the common interaction of mAR using touch screen based on any selected information. They propose a basic concept of the application with small feature sizes, specifically if the buttons and icons were to be clicked or touched by large fingers. This application was presented in 2-dimension and has been widely used in most applications that have the same function as a desktop computer in terms of mouse clicking. However, in the same study they emphasized this small size issue is natural and depending on the gesture interaction, based on user's finger tracking in front of a phone's camera [4]. While this approach can be applied to gaming and entertainment, as in Schal et al. [5] it has to be "in combination with standardized graphical interface objects (widgets or controls) which enables users to control arbitrary applications".

Therefore, an AR interface is a medium for information projection combined with the real world environment mapped with augmented reality surrounding in a single view. AR that is being deployed onto mobile devices, for example a smart phone, uses the smartphone's camera to analyze the physical environments in real time and overlay the augmented interface onto it. A mobile device acts as a magnifying glass to see what is occluded behind an object.

Types of mAR Interface

The *tangible AR* interface supports direct interaction by utilizing real equipments, physical objects and tools [1] such as handphone, car key, spectacles and etc. TaPuMa is one of the examples of the tabletop screen map uses personal belongings to interact and access any relevant information or direction from the map [6].

Collaborative AR interface refers to multiple displays that support co-located and remote activities. Co-location enhances the display and improves the physical collaboration using 3D interfaces. On the other hand, remote sharing allows multiple AR devices to be integrated with multiple locations, hence enhancing teleconferences [1].

A *hybrid AR* interface allows users to focus on a specific physical object. Once the system recognizes the object, relevant information will be displayed on screen [7].

Multimodal AR interface merges real objects and the system in the form of languages and behaviors namely speech, touch, natural hand gestures, or gaze [1]. In addition, multimedia elements are also present in the application to enhance user interaction [8]. For example, to explain the respiratory system, students will be able to learn using the interactive mAR application rather than examining a physical dummy object or just reading a textbook [8]. With a multimodal AR interface, it offers more enjoyment for students. In other words, the user may interact with the application by clicking the buttons just like a courseware and the augmented object will then be displayed [1].

Comparative Review

There are a number of important interfaces between education field and other applications. Based on a comparative review, it shows that only two interfaces are being applied in education; the tangible and the collaborative interfaces. In Creating Augmented Reality in Education (CARE) [9], uses mAR in clinical skills for lab treatment. The mAR helps to overlay those environments into a normal practice, hence increasing knowledge and enriching students' clinical skills, while simultaneously decreasing their nervousness. Unlike in London, United Kingdom, mAR supports the concept of self-centred learning and does not require extra hours to run lab or require academic staff/lab technician to monitor students from the Centre for Excellence in Teaching and Learning (CETL) [9]. The next application is Augmented Collaborative Campus (ACCampus). The ACCampus refers to the physical environments include wall class boards, windows and doors are equipped with Quick Response (QR) codes. In order to obtain information, students are able to interact with areas which have QR codes [10]. The Cultural Science Field Trip in another study by Ternier and Vries [11], mAR is utilized in a cultural science field trip using different types of game design, different delivery channels, and different pedagogical approaches using different case studies. This application is designed for navigation and exploration.

For advertisement, marketing strategy implements all types of interfaces based on the higher success rate of selling product efficiently [12] due to the mobility of mAR. It is a viable business opportunity since users can view it anytime, anywhere and further interact with the advertisement [13]. A study has proven that an advertisement employing the multimodal technique with interactive courseware function can deliver better information to the customer at their own pace [14].

In a creative atmosphere, AR enriches the information in presenting parts of a multimedia production specifically for storyboarding. The content can be updated through the server. Users are able to recall past comics from the previous week and the current week as one direction of the past story timeline.

In tourism, visual information is provided by the mAR application. Some of the information includes restaurants, places of interests, attractions, historical facts, Wi-Fi hot spots, ATMs, car parks, transportation routes, local news, weather, and many more [15]. The display of visual information is made possible through the concept of Point of Information (POI) where relevant information is being displayed and updated at any time any place, and in real time [15, 16].

Table 1 Comparison of the different types of mAR interfaces

	Types of mAR interface							
	Tangible		Collaborative		Hybrid		Multimodal	
Dimensions	2D	3D	2D	3D	2D	3D	2D	3D
Applications								
Education	√	√	√	√	x	x	x	x
Advertisement	√	√	√	√	√	√	*√	*√
							**Interactive courseware function*	
Storyboarding	√	√	x	x	x	x	x	x
Tourism	√	√	x	x	√	x	x	x

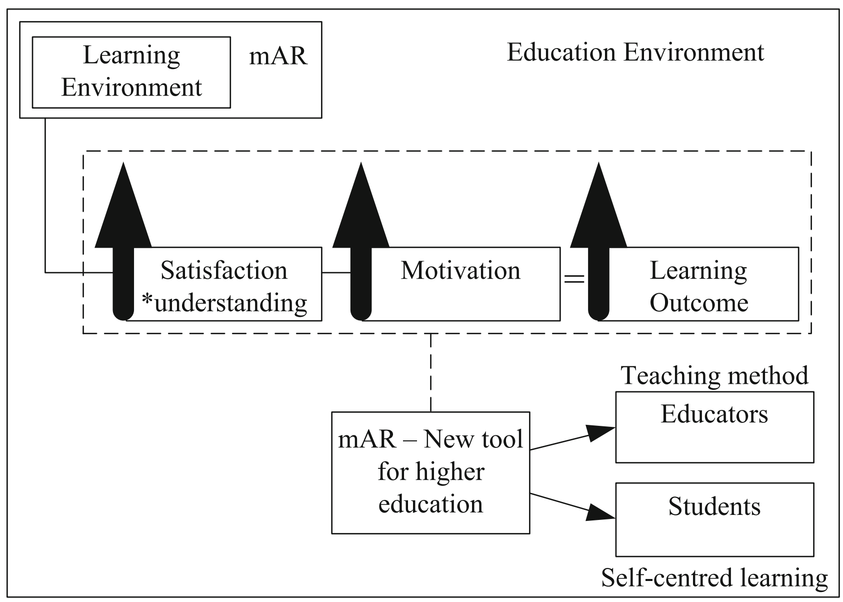

Fig. 1 Proposed mAR framework in the education environment

A comparative summary is shown in Table 1. Table 1 depicts the current types of mAR interfaces in numerous applications as discussed earlier. This may suggest that the current use of mAR has been generally lacking in few interfaces especially in education.

mAR Framework for Education

This paper proposes a framework which consists of combination of interfaces such as multimodal and hybrid as stated earlier. This framework supports the concept of student-centred learning with mobile-Augmented Reality (mAR) as an assistive learning tool in higher education environment (Fig. 1). It can be argued that mAR can provide benefits to learning activities by allowing faster access to information and provides information on demand, increases the student's motivation and engages in learning activities, making the learning process easier and more efficient, and help the students in understanding the concepts better [13, 17]. Based on the comparative analysis done (in Table 1) the multimodal interface has increased the sales in product advertisement. By proposing the same concept of hybrid and multimodal interface with the learning environment, it hopefully boosts the learning outcome of the students as well as their motivation, and it will also be beneficial to educators (Fig. 1).

According to Liu et al. [18] mAR has the potential to enhance the learning outcomes and educational experience if it is integrated effectively into the learning environment.

However, the implementation of mAR technology within the classroom learning is still weak [19, 20].

Piccoli et al. [21] draw the attention on learning outcome by using a Virtual Learning Environment (VLE) method. The term VLE is defined as "computer-based environments that relatively open systems, allowing interactions and encounters with other participants." [21]. The VLE as described above is where students are individually involved in a self-centred based learning environment and classroom environment together with diverse technologies as tools to support learning. Throughout this VLE framework, the learning outcome is measured through the effectiveness of these three dimensions, which include; performance, satisfaction and self-efficacy.

Human dimension comprises of students and teachers. It breaks down into maturity, motivation, technology comfort, technology attitudes, previous experience, computer anxiety and epistemic beliefs. While for teachers; technology controls, technology attitudes, teaching style, self-efficacy and availability.

In most cases in a virtual development, design is the vital issue that must be put into consideration because it delivers a great impact to the users. In the framework suggested by Piccoli et al. [21], the design dimension includes the learning model (objectivist, constructivist); technology (quality, reliability; availability); learner control (pace, sequence, content); content (factual knowledge, procedural knowledge, conceptual knowledge); and interaction (timing, frequency, quantity).

In this framework, the effectiveness is the dependent variable consists of three antecedents for instance performance (achievement, recall, time on task); self-efficacy and satisfaction. The effectiveness is measured through performance. It is more likely to achieve the goal; recalling what the subject has learned and completed the given tasks on time. Self-efficacy symbolizes people's opinion on how a learner is capable and competent in organizing and executing the required actions [21]. Whilst satisfaction represents the evaluation of the effectiveness of learning environment in an academic setting. In the field of teaching and learning environment, it is important to assess students' satisfaction because it relates to students' engagement in the learning activities, when and where they favor, learn at their own pace, and to mark the significant material to engender a positive interest.

By adopting the VLE's context in the mAR framework, learning outcome can be measured by quasi-experimental method in the future research. Referring to Fig. 1, satisfaction and motivation are the dimensions in the proposed framework. Satisfaction consists of quality and style of delivery, content and perceptions. By applying a multimodal and hybrid interface, it is likely to produce a high understanding for the students. Thus, will increase the motivation of the students to study a subject in greater earnest. In this paper, the motivations' characteristics are context, internal representation and process of learning. These characteristics will be as antecedents in the propose framework to obtain the effect of students' motivation and improve student learning outcome. An argument from Fuxin [22] stated that salient attention needs to be addressed on the students' learning side.

Therefore, this paper proposes mAR as a learning tool in higher education, focusing on the Biology subject. A study by Ganguly [23] has been carried out, Biology students decline to generate a long lasting understanding of a subject. By using mAR, experimental groups will be recruited and experienced the mAR to encounter the issue. The mobility of mAR using a multimodal interface can give students freedom in clicking and viewing the application at their own pace. mAR is the technology that can mobilize learning environment regardless of location and timing, and it has flexibility based on the students' need. In short, this self-centred learning technique can be supportive in catching up the subject.

Correspondingly, this mAR learning tool may also be beneficial for educators in developing innovative teaching method that required more understanding about any complex object in the learning environment. The result obtained from Fuxin [22] has strongly been challenged in recent years by Williams and Pence [24]. They suggested that educators have an important role to play in implementing technology for better learning.

Conclusion

AR is proven as a tool to strengthen motivation for learning [25, 26]. According to Lee [26], AR should be further explored in the context of being a mobile learning environment in higher education. Even though there were issues related to mAR in terms of equipment, integrating it with traditional learning methods, the cost of the development, maintenance and conflicts with emerging technologies at that time; these drawbacks have been resolved [26]. Therefore, mAR has the potential to capture learners' attention thus increasing motivation. In addition, according to Liu et al. [18], mAR has the potential to enhance the learning outcomes and educational experience if integrated effectively into a learning environment. This paper examined the types of mAR interfaces found in some important applications. As mAR is gaining attention in higher education, this paper presented a framework that comprises the important mAR interfaces that can enhance the use of mAR for learning. It is hopeful that the implementation of the proposed framework could bring about the motivation of student-centred learning.

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Automatic Extraction of Relationships Among Software Patterns

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Abstract

A software pattern is a great tool which perpetuates a proved knowledge on software engineering, and enables its reuses in different situations. The reuse of several patterns to elaborate a solution requires being aware of the relationships between patterns (inter-patterns relationships). These latter indicate what patterns can work together and in what manner. However, those relationships are difficult to discern when they are not explicitly mentioned within patterns, and their extraction is a hard task. In this context, the present paper exposes our approach of automatic inter-patterns relationships extraction, basing on a relationships analysis method.

Keywords

Automatic extraction • Inter-patterns relationships • Relationships extraction • Software patterns

Introduction

A software pattern offers a proven solution for a recurrent problem in software engineering. When addressing a particular topic, one often faces several related problems, a fact leading to the reuse of several patterns which are themselves inter related. However, inter-patterns relationships are difficult to discern when not explicitly mentioned in each pattern. Moreover, even if those relationships are explicitly listed, they do not consider all existing patterns. Furthermore, extracting inter-patterns relationships is evidently an onerous activity, especially with the growing number of software patterns. All these facts put patterns reuse into a disadvantage. Thus, relationships extraction will be better served by an automatic approach, able to handle any number of patterns, even belonging to different catalogues (patterns collections) or expressed in different forms.

Through this paper, we present our approach which improves an existing method of relationships analysis. The method we improve is the first automatic approach, analysing relationships between patterns from different catalogues, even when those patterns are heterogeneous, i. e. expressed in different forms. Our aim is to enable that method extracting more relationships among software patterns.

So, this paper is structured as follows: an introduction to software patterns and their advantages is presented in section "Software Patterns". Relationships between patterns are explained, and works related to this area are summarized in section "Relationships Between Patterns". An overview of an interesting method for analysing relationships between patterns constitutes the section "Detecting Relationships Between Patterns". Our contribution for the automatic extraction of relationships among patterns is presented in section "Detecting Relationships Between Patterns". Finally, we conclude this paper and give some research perspectives in section "Conclusion and Perspectives".

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_77,

Software Patterns

Descendant from Alexander architecture patterns [1], software patterns are an excellent resource solving software engineering problems, by bringing proven solutions. Usually, a software pattern includes the following elements [5]: Context refers to the situation and the problem that appear repeatedly. *Forces* describes constraints to be considered when applying the pattern. *Solution* refers to a concrete solution to solve the corresponding problem.

Several domains are addressed by different kinds of software patterns: Design patterns [5, 13] deal with object oriented software design problems. Process patterns [2] describe a proven, successful approach and/or series of actions for developing software. Embedded software patterns [12] describe solutions for designing embedded software. Reengineering patterns [8] handle reengineering and reverse engineering problems of object oriented software. Web application patterns [32] are interested in problems of software applications that are built using web technologies and made accessible via web browser, etc....

Independently of their application domains, software patterns bring many advantages [10]: Capture proven knowledge which produces effective results. Abstract the problem and the solution, so that the pattern can be reused in several situations and can be enriched if necessary. Act as a basis for the communication and understanding, since patterns names constitute a vocabulary.

However, the scale of published software patterns is reaching a point the need for tools to help users find, understand, and apply patterns becomes a critical need [17].

Relationships Between Patterns

Many relationships may exist between software patterns. Their role is to indicate which patterns can work together and how, so that one is able to reuse the related patterns.

Patterns can be composed together, to deal with a larger problem than those dealt with by each individual pattern. For example, according to [20] the patterns Flyweight [13] and Pool Allocation [11] are inter related via the relationship *Sequence*; so, it is interesting to detect this relationship in order to compose these two patterns. Indeed, in the environment in which the Pool Allocation Pattern can be applied, memory constraint is strongly restricted that is only static allocation is supported. Since the approach of the Flyweight Pattern provides a low memory usage, it is hence reasonable to consider applying the Flyweight Pattern after the Pool Allocation Pattern [20].

Patterns can be reused by each other, avoiding the creation of a solution from scratch. For instance, the patterns Review [15] and Release [15] are inter-related via the relationship *Uses*. So, it is interesting to detect this relationship in order to take advantage of the pattern Release in the versions management phase (of the pattern Review), and avoid creating a solution from scratch. Indeed, the Review pattern shows how to process a review during a project, and it is constituted of several phases, among others the phase of the versions management, for which the process patterns Release can be used.

Relationships between patterns enable user selecting the most suitable pattern for his need. For example, the patterns Capture A Common Vocabulary [15] and Capture Vocabulary Centrally [15] are inter related via the relationship *Refinement*. So, it is interesting to detect this relationship in order to reuse the pattern that gives the most detailed solution. Indeed, these two patterns solve the same problem, and show how a project glossary can be provided. However, the Capture Vocabulary Centrally pattern gives a more detailed solution on how to provide the glossary.

Another example is that of the patterns Chain of Responsibility [13] and Command [13], which are according to [19] inter related via the relationship *Variant*. It is interesting to detect this relationship in order to select the most suitable pattern for a given situation. Indeed, the two patterns have the similar purpose of reducing the responsibility: The purpose of the Chain of Responsibility is to allocate the limited responsibility to each object, and to achieve the responsibility by delegating the responsibility between objects. In addition the pattern enables the dynamic change of the processing order. The pattern Command encapsulates the responsibility of the command object, and range of responsibility of each object is reduced [19].

Other kinds of relationships can exist between patterns. So, many researchers focused their interests on inter-patterns relationships:

- Walter Zimmer [35] is the first to define relationships between object oriented design patterns. He used in his work the Gang of Four patterns [13]. According to Zimmer, three kinds of relationships may exist between patterns: One pattern can use another pattern. One pattern can be combined with another pattern. One pattern can be similar to another pattern.

  Other studies have succeeded to this work, which were also interested in defining inter-patterns relationships. For instance, the work [9] defines relationships in order to organize patterns and to select them from collections.
- Prabhakar et al. [25] propose a graphical model called DDTM (Design Decision Topology Model), in order to represent design patterns and analyze relationships between them. In that work, relationships are assimilated to the links between the graphs representing the patterns, and each pattern is considered as a

topology of Design Decisions [4, 18]. However, this work is limited to design patterns, as it is based on design decisions.

The method of Kubo et al. [19] that treats software patterns is the first automatic approach, able to analyze relationships between heterogeneous patterns, and between patterns belonging to different catalogues.

Detecting Relationships Between Patterns

As explained earlier, even the relationships between patterns are very important, it remains difficult to discern them if they are not explicit in each pattern. In addition, even when those relationships are explicitly listed in a pattern, they are often limited to intra-catalog relationships. Very few patterns list relationships towards patterns in other catalogs. For example, out of 170 patterns collections inspected in a survey [17], only one instance lists references to patterns in other catalogs [29].

In this context, the need appear for an automatic method, which analyzes relationships between patterns even if those latter are heterogeneous, or if those patterns belong to different catalogs. And Kubo et al. method [19] came to answer this need.

Kubo et al. [19] method is based on its own pattern model, uses many text processing techniques and uses the cosine similarity to analyze relationships between patterns. It represents a pattern application as a context transition from a starting context to a resulting context, and includes the pattern forces in the model (because patterns that differ only in term of forces are considered as different patterns). Kubo et al. method considers seven types of relationships between two patterns. Namely [19, 34]: Starting-Starting, Resulting-Resulting, Resulting-Starting, SubInStarting, SubInResulting, Same, SimilarForce.

Kubo et al. method attracts particularly all our attention for the following reasons: It is an automatic method, which means that it is able to treat any number of patterns. It deals with patterns from different domains, and is the only approach able to deal with process patterns [33]. It can analyse relationships between patterns belonging to different catalogues, and between heterogeneous patterns.

However, this method presents a main drawback: it can't analyze the relationships Refines and Uses that are ubiquitous in the literature, are on the basis of the definition of other relationships and their definitions are straightforward [23]. Indeed, Refines and Uses are addressed by many works such as those presented in Table 1. Through these works, the two relationships carry different appellations but keep similar semantics.

Table 1 Different appellations of refines and uses

Works	The uses relationship	The refines relationships
Zimmer [35]	Uses	–
Buschmann et al. [5]	Uses	–
Meszaros and Doble [21]	Uses Is used by	Specialize Generalize
Henney [16]	–	Specialization
Rieu e al. [26] and Conte et al. [6]	"Utilise"	"Raffine"
Volter [31]	Is required to make a pattern X works	Is a specialization
Gnatz et al. [14]	"Raffine"	–
Hagen and Gruhn [15]	Use	Refine problem Refinement
Tran [30]	Use	Refinement
Prabhakar and Kumar [25]	Uses	Subsums

Our Approach

Our approach towards an automatic extraction of relationships among software patterns is based on the analysis method of Kubo et al. This latter uses several texts processing techniques, such as stop word removal [27], stemming [24], the TFIDF term weighting method [28], vector space model [27] and the cosine similarity. We use in our approach the pattern model of Kubo et al., which enables us treating most heterogeneous patterns. The value-added of our work is the possibility to extract the relationships Refines and Uses among software patterns.

We propose in our approach an auxiliary which is the *Inclusion* analyser. The existence of *Inclusion* between two texts means that in addition to being similar, one of these texts contains the other. Let's have two texts T1 and T2 consisting of one or more terms. T1 *is Included in* T2 means that the following two conditions are true.

- T1 is similar to T2: to signify that the terms of T1 exist in T2, which means that T2 treats of the T1 subject. To evaluate this condition, we calculate the cosine similarity between the two texts. Their similarity value has to be larger than the Similarity threshold.
- T2 is larger than T1: to signify that T2 contains T1 in addition to another content. To evaluate this condition, we calculate the size of each text after eliminating stop words, and then we compare the sizes of the two texts by calculating the ratio of the sizes difference to the size of the largest text. The ratio has to be larger than the Sizes Difference threshold.

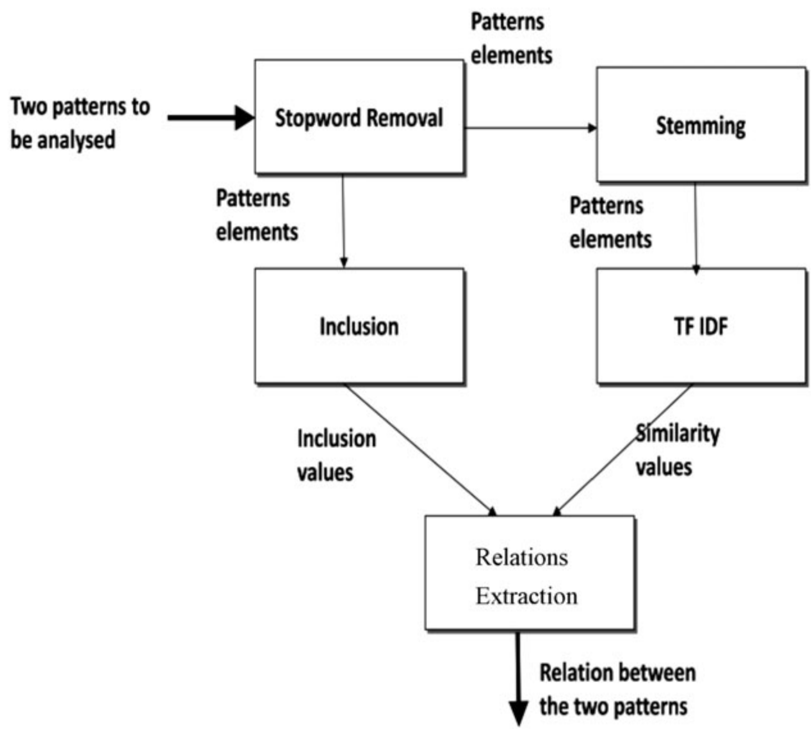

Fig. 1 Synopsis of our relationships extraction approach

Figure 1 briefly describes our approach to extract relationships. Two patterns expressed in the model of Kubo et al. (consisting of the three elements Starting *Context*, Forces and Resulting Context) are input. We operate on the removal of stop words. Then, on the one hand we calculate the inclusion between the different elements of the two patterns, and on the other hand, we apply the stemming and then the TFIDF weighting to calculate the cosine similarity between the elements of the two patterns. Thus, we obtain on one hand the values of inclusion between the elements of both patterns, and on the other hand the similarity values between them. The final step is to calculate the values of each possible relationship between these two patterns, as explained in the following paragraph.

Relationship Extraction

Let's have P1 and P2 two patterns expressed in the model of Kubo et al.

P1 *Uses* P2 means that the following two conditions are true.

- Condition1: The P2 Starting Context *is Included in* the P1 Starting Context.
- Condition2: The P2 Resulting Context *is Included in* the P1 Resulting Context.

Condition1 means that the problem addressed by P2 is a sub problem of that treated by P1, while condition2 means that the result of P2 application is a sub set of the result produced by the application of pattern P1.

P2 *Refines* P1 means that the following tree conditions are true.

- Condition3: The P2 Starting Context is similar to the P1 Starting Context.
- Condition4: The P1 Starting Context *doesn't Include* the P2 Starting Context.
- Condition5: The P1 Forces *is Included in* the P2 Forces.

Condition3 means that both patterns P1 and P2 deal with the same problem. Condition4 insures that P1(the pattern being refined) doesn't deal with a problem larger than the one dealt by the pattern P2, whereas condition5 means that constraints imposed on P1 are a sub set of the constraints imposed on the pattern P2.

Application Examples

Here is an example of our extraction method, applied to the patterns *Process Follows Practice* [3] (called P1) and *Scenarios Define Business Processes* [22] (called P2). No relationship between these two patterns is explicitly indicated. We process the extraction as follows:

First, we compare the different elements (*Starting Context* that we note SC, *Forces* and *Resulting Context* that we note RC) of the two patterns P1 and P2 in terms of similarity and *Inclusion*. We obtain the results shown in Table 2.

Table 2 Comparison results of the patterns elements

Compared elements	Results
SC of P1 and SC of P2	Similarity = 0.132
	SC of P1 includes SC of P2 = True
	SC of P2 includes SC of P1 = False
RC of P1 and RC of P2	Similarity = 0.042
	RC of P1 includes RC of P2 = True
	RC of P2 includes RC of P1 = False
Forces of P1 and Forces of P2	Similarity = 0.164
	Forces of P1 includes Forces of P2 = True
	Forces of P2 includes Forces of P1 = False
RC of P1 and SC of P2	Similarity = 0.113
RC of P2 and SC of P1	Similarity = 0.130

Table 3 Relationships evaluation

Relationship	Its value
P1 uses P2	0
P1 refines P2	0.148
P2 uses P1	0
P2 refines P1	0
Same	0
Starting-starting	0.132
Resulting-starting (P1 then P2)	0.113
Resulting-starting (P2 then P1)	0.130

After that, we evaluate each relationship between those patterns. For the relationships Same, Starting-Starting and Resulting-Starting, we use the analysis method of Kubo et al. Whereas for the relationships Uses and Refines, we exploit our propositions given in the previous paragraph. We obtain the results shown in Table 3.

Finally, as in Kubo et al. method, the strongest relationship among the eight types (P1 Uses P2, P1 Refines P2, P2 Uses P1, P2 Refines P1, Same, Starting-Starting, Resulting-Starting (P1 then P2), Resulting-Starting (P2 then P1)) is assumed as the representative relationship. So, we conclude that the pattern P1 *Refines* the pattern P2.

Indeed, this result is correct for the following reasons: Both P1 and P2 are organizational patterns, that can be applied for documenting a process and its evolution. Pattern P2 shows the best mean to document the requirements of a process; whereas pattern P1 refines it and gives a more detailed solution, showing how to improve a process while insuring that the documentation represents with accuracy this improvement.

Another application example is that considering the patterns *Application Design is Bounded By Test Design* [7] (called P1) and *Prototype* [7] (called P2). No relationship between these two patterns is explicitly indicated by their original author.

Table 4 Comparison results of the patterns elements

Compared elements	Results
SC of P1 and SC of P2	Similarity = 0.122
	SC of P1 includes SC of P2 = False
	SC of P2 includes SC of P1 = True
RC of P1 and RC of P2	Similarity = 0.205
	RC of P1 includes RC of P2 = False
	RC of P2 includes RC of P1 = True
Forces of P1 and forces of P2	Similarity = 0.170
	Forces of P1 includes Forces of P2 = True
	Forces of P2 includes Forces of P1 = False
RC of P1 and SC of P2	Similarity = 0.099
RC of P2 and SC of P1	Similarity = 0.038

Table 5 Relationships evaluation

Relationship	Its value
P1 uses P2	0
P1 refines P2	0
P2 uses P1	0.164
P2 refines P1	0
Same	0.164
Starting-starting	0.122
Resulting-starting (P1 then P2)	0.099
Resulting-starting (P2 then P1)	0

First, we compare the different elements of the two patterns P1and P2. We obtain the results shown in Table 4.

Then, we evaluate each inter-patterns relationship between P1and P2. We obtain the results shown in Table 5.

Finally, considering the strongest relationship, we conclude that the pattern P2 *Uses* the pattern P1.

Indeed, this result is correct for the following reasons : Pattern P2 aims at validating the customer requirements, in order to prepare the next phases of the software project. P2 recommends in its solution the use of tests to validate these requirements. In this purpose P2 can use pattern P1, which shows how to prepare and proceed the tests, and which avoid to the user the creation of a solution from scratch.

Conclusion and Perspectives

This paper presents our automatic extraction approach of relationships among software patterns, which is based on the analysis method of Kubo et al.. We improve the afore mentioned method to allow it extracting the Refines and Uses relationships, since those latter occur very often between patterns and are on the basis of other relationships definitions. Our approach takes into account the *Inclusion*, for which we propose an analysis.

Concerning the current limitation of our approach, it is mostly the drawback inherent to the model of Kubo et al. used to represent a pattern. Indeed, this model is composed of three elements (Starting Context, Forces and Resulting Context), so a pattern that doesn't include one of these elements can't be modelled, and relationships can't thus be extracted on it. We are working towards the resolution of this problem, to enable our approach to deal with more patterns forms, as we do with patterns lacking of RC [36].

Other lines of future work include the extension of the method in order to offer the functionality of Patterns Retrieval. This latter offers to a user who have a particular problem, all available patterns that treat this problem.

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Smart Email: Almost An Agent Platform

Magdalena Godlewska and Bogdan Wiszniewski

Abstract
Network organizations suffer today of information overload and strain that rise their operational costs. One of the reasons of that is the dominance of email messaging as the principal means of document exchange between their workers. Proactive documents can rationalize these costs and augment email systems with a process view based on collaboration patterns.

Keywords
Network • Email • Overload • Patterns

Introduction

The basic feature of a networked organization is some computer-mediated communication facility that enables individuals working together for a common purpose to link across boundaries in order to interact and exchange information. Collaborators, often called *knowledge workers*, exchange documents constituting units of information, and more recently—with the advent of active documents, also units of interaction [1]. Despite of growing capabilities of such documents [2], especially with regard to agent-like mobility [3], their use in networked organizations is still limited. There are at least two reasons for that.

One is the dominant position of email as the most popular computer mediated communication in the workplace: a simple textual form combined with a possibility to disseminate attachments in any format with just one click to one or multiple recipients, convenient support for asynchronous work (read and respond later, copy or archive messages for further use) have made email messaging a truly enabling technology for networked organizations. On the other hand, ordinary emails provide no direct support for task coordination, neither for monitoring activities extended in time nor controlling who needs to work with whom. Most often knowledge workers must manually implement procedures they know and (hopefully) understand. In doing that they must not make mistakes, as they cannot be controlled in what they send and where, as well as have a limited capability to distinguish and trace their concurrent activities. This leads to such negative phenomena as email *overload* and *strain*, generating measurable operational costs for the organization [4].

Another reason for a limited interest of networked organizations in active document platforms is that they, unlike email systems, fail to promise long term stability. They are in a permanent experimental stage—upon release of a newer version the previous one quickly gets obsolete. Moreover, knowledge workers are often expected to acquire additional skills to administer and configure their personal devices in order to run a particular platform.

By subscribing to email as the principal means of communication, today's knowledge workers tend to use it for *ad hoc* task management—without any standard collaboration patterns, for which no email system yet could provide a sufficient support. One reason is probably that task management involves multitasking, which in principle is not natural for the human mind. In consequence, attempting manual implementation of pre-emption (interrupting and resuming of tasks) by knowledge workers is perceived by them as

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_78, © Springer International Publishing Switzerland 2015

tedious, often resulting in reading email messages in a different order then intended by their senders, or not reading email at all [5].

Personal Email Management Tactics

People try to combat the feeling of email overload and strain by developing individually various email management tactics. Research on that subject [6] clearly indicates that there is no universal solution, and various tactics have their roots in diverse psychological profiles of knowledge workers. For example, some people would like to check email as soon as a new message has arrived, some only at specific times of the day, whereas others do that each time they open their personal device and connect to Internet. Some are happy to keep their inbox size small, others prefer to keep messages in the inbox as a reminder of things to do. In consequence, any message may be deleted from the inbox immediately after reading, as well as kept there for reading it later. Alternatively, messages may be filed into separate folders as soon as they come for further processing, or filed there later after processing.

Unfortunately, all of that is just a substitute of real task management mechanisms—aimed mainly at creating a sense of complacency by each individual collaborator, rather than enabling global coordination of activities performed by all collaborators.

Email Management Tools

Personal email management tactics are used by knowledge workers to make email messaging appropriate for their collaboration. In an attempt to address their needs in a more organized fashion, developers of email tools, from Microsoft Outlook—a popular commercial application, or Thunderbird—a free software license application, to Web-based email services, such as Hotmail, Yahoo! or Gmail, introduce regularly various features for the effective management of the influx of messages requiring user actions [7]. Standard solutions include sorting of messages with regard to the sender, recipient, or date, keyword search in the message body or header, indexing and tagging of the message text, as well as filtering with user-defined patterns. The effort is focused on analyzing the individual message and the inbox as a whole to relieve message recipients from excessive work.

Functionality of the locally installed email clients may be further extended with various add-ons: enabling email clients to identify networks of people, organizing messages automatically into virtual folders with regard to correspondents, attachments, dates or categories, even attempting mechanisms for building ad hoc workflows by creating tasks and appointments from messages [8].

Document Centric Approach

Although increasing capabilities of today's email management tools may look impressive to funs of particular technologies or global services, the main focus is on providing comfort for individual workers rather than a group of collaborating workers. This is because the email messaging metaphor concentrates on isolated activities of individual workers and lacks a holistic process perspective—where activities of individual workers form discernible sequences of events. In other words, a receive-reply pattern associated with handling ordinary email by a single worker precludes more complex collaboration patterns that may occur in the context of the entire process involving many workers. This deficiency of email metaphor does not show up as long as email is used just for exchanging textual messages, often chosen as an attractive alternative to telephone conversation for its asynchronous mode of communication. However, when some formal documents are attached to messages in order to be processed by many workers—who may implement arbitrary complex business procedures, the lack the process perspective becomes a problem. In that regard the most important challenges to email are [9]:

– *tracing* of concurrent activities for proper distribution and selection of work, as well as for acquisition and synchronization of information from external sources,
– *controlling* importance of activities implied by the received document content in terms of the required effort and time to complete them,
– *management* of activities extended in time and monitoring tasks they belong to, especially with regard to causality analysis of the related events,
– *combining* received messages in order to file all documents related to a particular activity,
– *overview* of the current activity in the context of task execution and its resources.

Clearly, pushing email systems beyond the receive-reply pattern results in the email overload and strain phenomena mentioned before. This is because more complex collaboration patterns have to be implemented manually by collaborating workers, directly confronting the challenges mentioned above without any help from the email system.

In order to eliminate that we advocate a document centric approach, where documents themselves are responsible for communicating content to the respective workers, and coordinating activities performed by them during the entire process. We propose augmenting email messaging with proactive documents, capable of initiating process activities on their own by interacting with individual workers and their

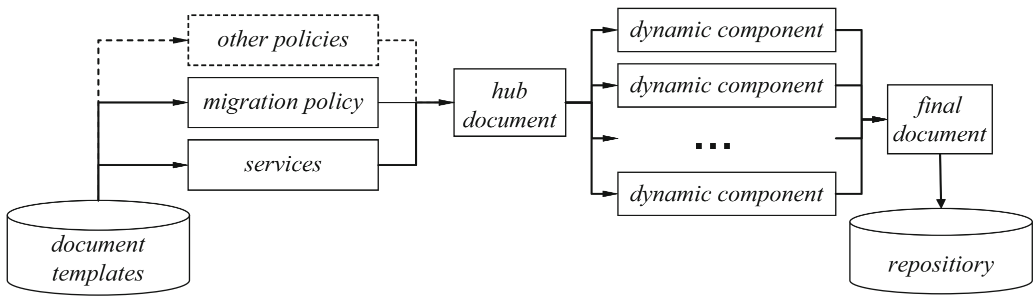

Fig. 1 A mobile interactive document system. Active document components can migrate single-handedly in a system of physically separated devices and interact with their users

personal devices. In doing that documents may use various services, including embedded document functionality, local system services, or external (third-party) services. Moreover, a dedicated embedded functionality of a document, combined with services of an email client installed locally on the worker's device provide mobility of documents; they are sent between collaborators' devices as email attachments. This idea is outlined in Fig. 1. The process (workflow) is initiated by a worker who sends a document with a *migration policy* embedded in it. The initiating worker is called the document *originator*, whereas the *hub-document* aggregates various components explained in section "Distributed Workflow Enactment". When travelling across a system of distributed devices a document may split in component documents, merge them, duplicate, add new components, delete some other ones, and so on. Upon completing its mission a document performs the final activity of its workflow, which is serialization and storage in a repository.

Owing to proactive attachments, the email system can get smarter to become *almost* an agent platform. "Almost" makes a big difference here—our model of a mobile interactive document system brings to the network organization all the benefits of multi-agent systems, such as self-organization and self-steering in implementing arbitrary complex collective behaviors with simple individual agent behaviors, without a need to implement a full-size agent platform that would have to be updated regularly, conform to standards currently in force [10] and require trained administrators to run it.

Communication of Content

Upon delivery of a document, its content data should be accompanied by a description enabling the receiving email client to pick up an appropriate mechanism making them usable to the knowledge worker. This is because the native representation of the document content may be subject to encoding transformations when passing through mail transport protocols with various data limitations. This issue has been successfully addressed by the Multipurpose Internet Mail Extensions (MIME) standard, enabling email users to include practically any content in email messages. MIME defines several header fields for message attributes. In particular, the *Content-Type* message header may specify one of several pre-defined top-level media types, and a variety of specific subtypes of the initial type. The list of possible types and subtypes is open, allowing for new types to be invented and registered with Internet Assigned Numbers Authority (IANA) in the future [11].

Although MIME types can effectively identify to the receiving worker what content has been put into his/her mailbox, performing an activity by the recipient may require additional arrangements. One is when it becomes necessary to make an a-priori agreement with the sending worker on what tools shall be used for the identified (known) content. Another is finding tools for the content type identified as nonstandard.

Standard content type: Despite of commonly agreed document formats, handling of their content by popular tools may differ. Examples include formatting of tables with merged cells, or page formatting due to font substitutions by word processing tools. Differences of this kind are irrelevant to the organization providing its workers with systems and tools of the same make and version, putting them in some confined space and requiring to strictly follow the office timings. But this assumption is no longer realistic in a dynamic virtual organization setting, where knowledge workers are spread over a large area, change their locations frequently (either when on business travel or just being between office and home), work outside regular working hours, and use different (most often their personal) execution devices. Handling of this problem by the proactive document, with embedded functionality dedicated to the particular type of content, or at least able to adapt the document content to the local device specificity, seems to be more appropriate than forcing a monoculture of document processing tools across the organization.

Nonstandard content type: Content type unknown to MIME is indicated with a generic application/octet-stream identifier, so the receiving email client has no hint on what tool to use to open the document. If never dealt with such a content before, the receiving worker may reasonably expect instructions attached to the document on what tool to use to perform the activity. This situation may involve even a series of messages to negotiate a solution if conflicts arise. Sometimes email users may agree to exchange private content types without registration with IANA. MIME provides for that identifiers with the special 'x-'prefix. Since not registered and nonstandard there is no guarantee that they will not be replaced by something else in the future. Unfortunately, a nonstandard content necessitates additional adjustments of local systems, despite of reaching agreement on a document format by collaborating knowledge workers. Configuration of their local systems often cannot be automated if based only on the received content type descriptions—so upon receiving documents, further consultations (most likely by exchanging additional mails) may be required.

Coordination of Activities

In a mobile interactive document system shown in Fig. 1 individual knowledge workers perform activities on documents independently, using their physically separated personal devices, and yet collaborate on achieving a common goal. It is possible owing to the migration policy embedded in each proactive document that they receive for processing. This policy defines for each document a workflow process, which combines activities and transitions between activities in specific document flow patterns; they implicitly involve workers in the collaboration process and provide process wide coordination of their respective activities. Owing to that, implementation of business procedures in a network organization may be greatly simplified and eliminated from the everyday routine of knowledge workers overwhelmed with mass influx of emails.

Based on the pioneering work of van der Aaalst it can be shown that arbitrary complex workflow processes in real organizations are composed of elements from a relatively small and well defined set of collaboration patterns [12]. We have analyzed a subset called by the authors control-flow patterns under the assumption that the transport layer for document migration is based solely on email services. As a result of our research three categories of document-flow patterns have been identified: *distributed state* patterns, with transitions depending only on the state of a single activity performed by the worker at some location in the system, *coupled state* patterns, with transitions depending on states of two or more activities performed simultaneously by two or more workers at separate locations in the system, and *embedded state* patterns with block activities implemented as subflows [13].

Distributed state patterns: These document-flow patterns describe situations in which the next activity to be performed can be determined solely on the state of the current activity. We distinguish four such coordination patterns: *sequencer*, *splitter*, *merger* and *iterator*.

Document sequencer involves a knowledge worker, who upon completion of his/her activity sends to another worker one or more resulting document components in a sequence.

Document splitter may be *cloning* or *decomposing*. The cloning splitter creates identical copies of the received document, while the decomposing splitter partitions the received document into separate fragments. The resulting document components, either copies or fragments, are next sent to the respective knowledge workers specified in the migration policy of the previously received document.

Document merger, complementing the document splitter pattern, may involve various document functionality, depending on whether the preceding splitter has been cloning or decomposing. It may be as simple as the concatenation of chunks of text, or quite complex as in the case of synchronizing documents with sophisticated content merging algorithms. In any case the respective functionality enabling that is brought by arriving document components to the receiving worker's device.

Document iterator enables repeated execution of a sequencer pattern controlled by a condition specified in the respective document migration policy. Functionality brought by the arriving document to the respective worker's device can determine loop termination based on the current document content.

Coupled state patterns: Sometimes completion of the activity performed by one worker may require notification on the state of some activity performed by another worker somewhere in the organization. Collaboration patterns enabling that involve the notion of asynchronous signals, sent between different parts of the workflow process. Such a signal may be implemented in a network organization in many ways, e.g. with texting, phone calls, instant messaging, or just "out-of-bound" email messages. We distinguish three collaboration patterns of this kind: *deferred choice*, *milestone*, and *cancel activity*.

Deferred choice and milestone patterns are used to deal with situations when the current activity of one worker has to be blocked until a signal notifying on some external event has been received from another worker. Both patterns require a proactive document to provide a worker's device with a semaphore and embedded functionality to handle it. Initial value of the semaphore is closed, so if the signal from another worker has not been received, the current activity is advanced as far as it can and the document is put aside to the wait queue. Upon receiving a signal the waiting activity is resumed. If the signal has been received by the worker's device before the current activity has been started (or the respective document component not yet received), the relevant signal notification is stored by the device to enable completion of the respective activity when the document is received.

Deferred choice is used when sending a given document has to be postponed until the worker gets information to whom it should be sent. Milestone is a simplified version of deferred choice, with a signal without any specific data associated with it, and which only purpose is to block some activity of one worker by another one.

If when performing an activity by the current worker it turns out that some activity performed by another worker has to be cancelled a special cancellation signal has to be sent. Three cases are possible. One is that the document may have not yet been delivered to another worker, so the cancellation signal should be stored in the internal table of the remote device to enable immediate deletion of the document as soon as it is delivered. Another is that the document is currently being processed by another worker, so its deletion may be problematic if the relevant worker has advanced to the point where some resulting documents have already been sent. Note that no semaphore is needed here, as the decision on canceling the activity and deleting the related document is immediate for the receiving device. Finally, the document may have been already processed and sent to another worker, so cancelling that particular activity does not make sense any more. In consequence cancellation of activity may fail.

Embedded state patterns: Performing the activity by a worker may sometimes require a subprocess to be delegated to someone else, with activities not specified originally in the migration policy of the arriving document. States of such a subprocess are embedded in the state of the current activity enabling that. If the current worker is authorized to extend the original migration policy of a document with new activities of his/her choice, they constitute an *internal subprocess*. Neither the structure of the internal subflow nor identity of added workers have to be known earlier to the document originator. Alternatively, a subprocess may be considered *external* if started implicitly by the current activity calling some external service. In the case of an external subflow, the structure of a subflow and identity of thus "subcontracted" workers are not known to the document originator as well as to the performer of the current activity. The separation between the main process and the external subprocess is provided by some intermediary server, to which a document to be processed is initially uploaded, and later downloaded when completed; in between, the subcontracted external process downloads it for processing and upon completion, uploads back to the intermediary server. Upload and download service calls are assumed to be blocking, i.e., the current (contracting) worker and his/her unknown contractors wait until the respective service call has finished. Note that in such a case the external process may be implemented in any technology, not necessarily as a document centric application.

Distributed Workflow Enactment

Our generic document architecture can provide email clients with sufficient functionality to support distributed workflow enactment of proactive email attachments. Implementation of a system shown in Fig. 1 requires two entities: a bundle of files sent by email in one package and a local workflow engine that can be implemented as a stand-alone email client application or a plug-in to any popular email client.

The MIND Architecture

Our proactive document architecture is outlined in Fig. 2. Its central *hub-document* object aggregates data and resource objects. Data objects are *parts* with a passive document *content* of a specific *mime-type*, whereas resource objects include the document *migration-path*, its *services* and *workers*.

The migration-path object includes the relevant process objects, which correspond to standard elements of XPDL [14]: *activity* objects, specifying the respective process activities to be performed, and *transition* objects, specifying the migration-path segments in between activities of the workflow.

Each activity object indicates its *performer*, who may be a worker, located at a specific *email-address*, a service specified by some *uri*, or both.

Local Workflow Engine

Objects of the mobile interactive document, shown in Fig. 2, enable interaction between its content and the worker as well as his/her execution device. Their lifetime, however, is limited to the activity phase of a mobile document, starting upon document arrival to the worker's execution device and ending when the document is sent to the next worker. During the transition phase, between leaving one worker's device and arriving to another's one, document objects are serialized and packed in the message. A special agent, external to the document, is needed to handle switching documents between the activity and transition phases; the agent, called a Local Workflow Engine (LWE), has been implemented in our system as a lightweight email client, installed on each worker's device participating in the process. Generic

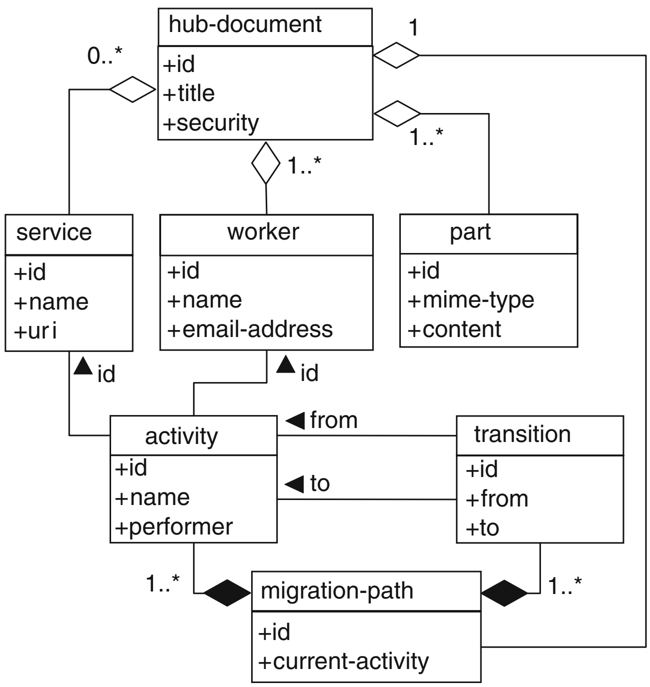

Fig. 2 A mobile interactive document architecture. Document activation involves binding of the received message data with executable objects

functionality of LWE is to retrieve messages with serialized documents from the worker's mailbox, activate their objects, and when the current activity is to be concluded, serialize them and pack into a message submitted to the worker's email server for sending to the next worker. A state diagram of the LWE client is shown in Fig. 3. Depending on the particular pattern the current activity belongs to, one or more messages may be retrieved from the mailbox (sequencer or merger patterns), as well as one or more messages may be submitted for sending (sequencer or splitter patterns). In any case, the necessary functionality to enable LWE to determine how many messages to send and to whom, is brought to the worker's device by the document itself.

Class Roster Example

Validity of implementing our mobile interactive document technology on top of standard email services has been demonstrated in a realistic class roster application. Its idea is outlined in Fig. 4. Originator of the grade roster document is the Registrar's Office (RO), which recipient is the Course Leader (CL). CL runs his/her own subprocess of collecting credits from instructors during the entire semester; structure and implementation of that subprocess is irrelevant to RO. While RO may use an on-line grade system for one-time roster submission and approval, CL is free to implement his/her credit collection process in any way. Let it be email, as course instructors are very busy, and when out of the campus network, keen to use their personal mobile devices. We have demonstrated in [13] that dynamics of the grading process, involving both scheduled and unpredictable events, such as project assessment or homework collection for the former, and grade correction or disciplinary actions in a case of academic misconduct for the latter, may be effectively handled with the collaboration patterns introduced in section "Document Centric Approach". Screenshots of this application illustrating some LWE states shown in Fig. 3 are shown in Fig. 5.

Related Work

The idea of services embedded in a document may be found in the literature dating back to the late 1990s. A prominent example has been a *placeless document* introduced in [2], which can provide users with *active properties*, triggered when systems or workers attempt certain operations over it. Properties may be exercised individually by performers at sites where their activities actually take place, can migrate with a document when emailed or copied, and coordinate document transitions from one state to another with workflow applications. These applications, however, can only be external to the system, as placeless documents are *reactive* and cannot initiate transitions on their own. The concept of a *proactive document*, capable of traveling from computer to computer under its own control has been demonstrated in MobiDoc, a compound document-agent platform [3]. Unfortunately, MobiDoc is not forward compatible in the fashion advocated by MIME, i.e., is not able to cope with unknown (future) data formats.

Obviously, agent platforms may incorporate the notion of workflows. One example is WADE [15], providing a special class of agents embedding a micro-workflow engine, capable of executing workflows—implemented as instances of a special Java class compiled before launching the workflow. It follows the classic central workflow enactment philosophy, and differs from it only in decentralization of a global process state into local process states controlled by micro-workflow engines running inside agents.

Conclusion

MIND documents, with built-in workflows, taking an advantage of long term stability of email systems, and their relative independence of network availability—practically needed only for document delivery to the worker's mailbox before performing an activity, and sending it out after concluding the activity (see Fig. 3), can offer an attractive alternative to classic agent platforms. Each MIND document

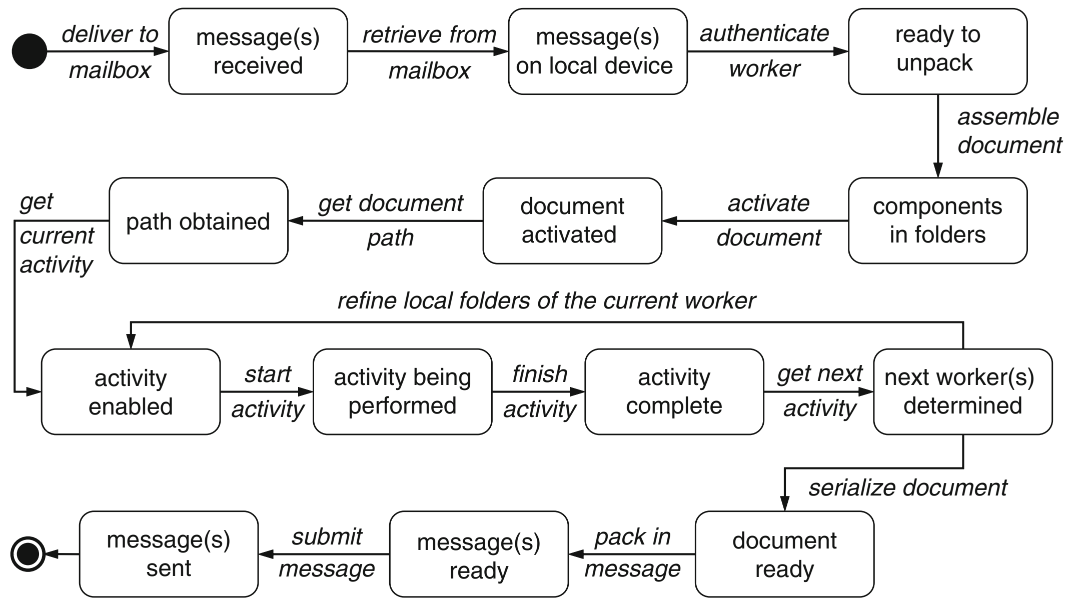

Fig. 3 States of a local workflow engine. Document lifetime on the worker's device starts on copying the message to the worker's device from the specified mailbox. Activity is started upon document activation and terminates upon acceptance of the resulting document by the worker. Document is packed into a new message and submitted to the mail server for sending it out to the next worker

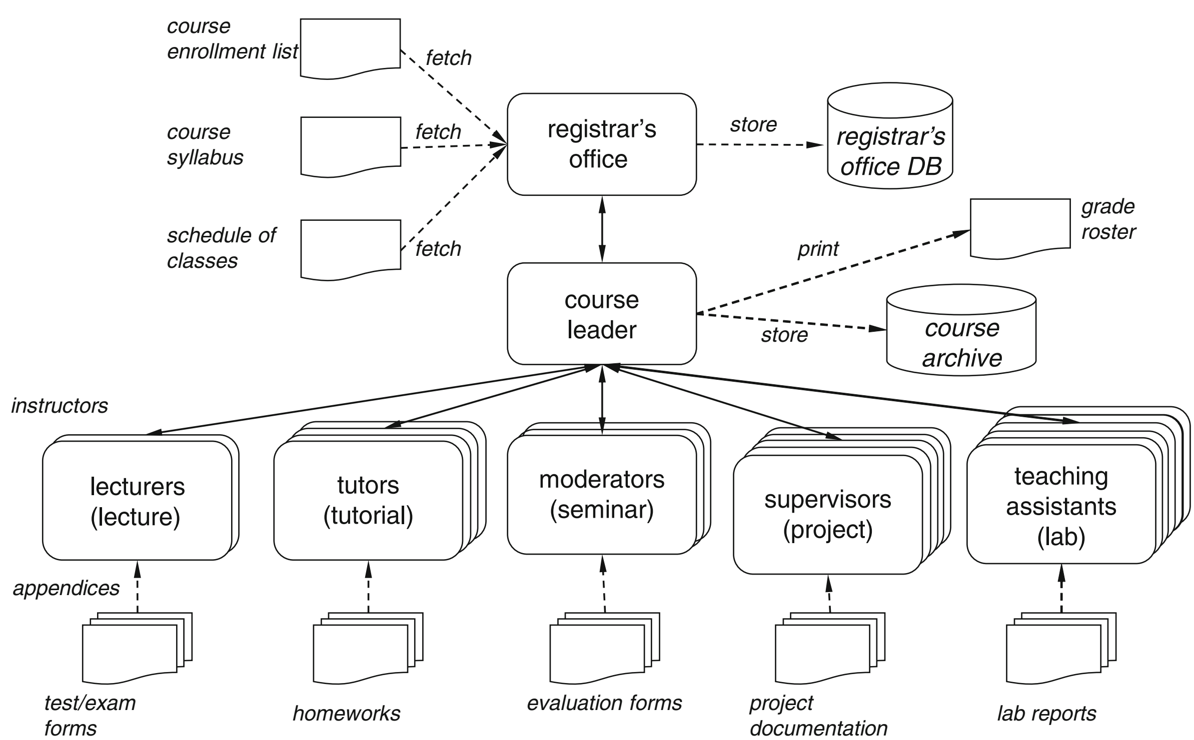

Fig. 4 An academic course grading example. A network organization is a university department running a course delivered to a large group of students. Knowledge workers are instructors responsible to assess and collect credits for all types of tests and assignments, scheduled for the entire semester and specific to their classes

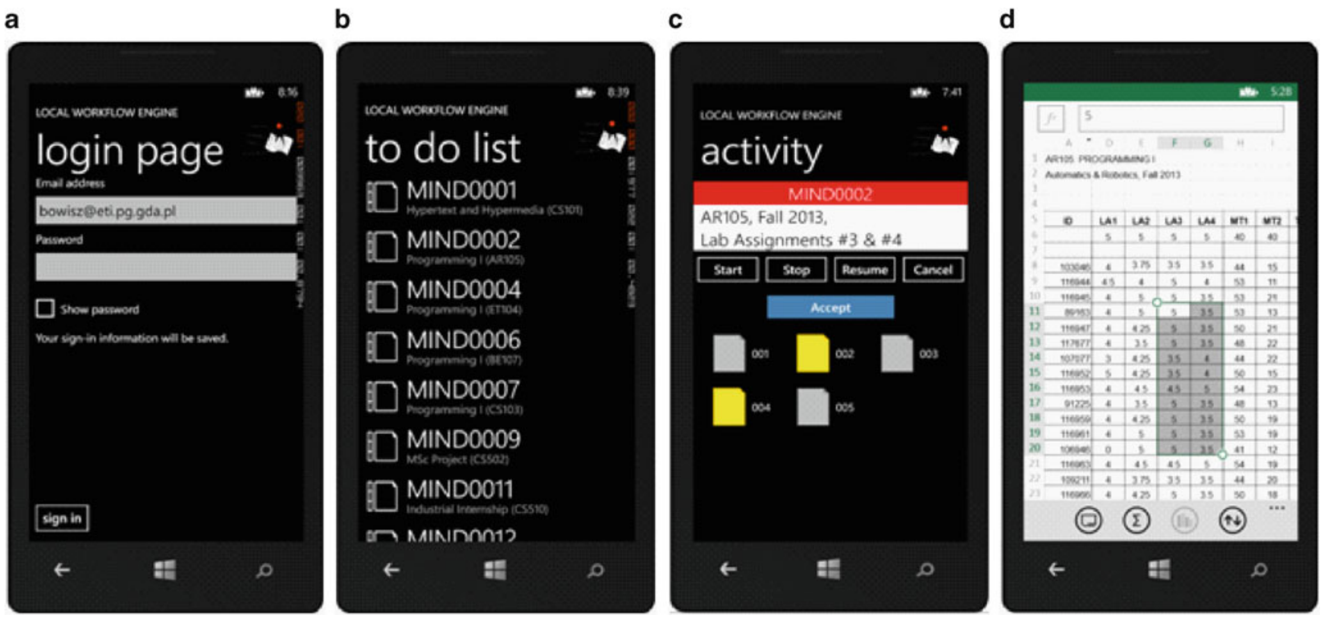

Fig. 5 User interface of the class roster application. Login page data (**a**) indicate to LWE from which mailbox MIND messages should be retrieved. Documents representing each workflow case the worker is involved in are listed in one 'to do' list (**b**). By choosing a case its current activity status is displayed (**c**) to the worker. If all required parts of the document are in place, interaction with its content can start, e.g. filling the class roster sheet with grades using the locally available Excel tool (**d**)

is the sole depositary of its internal state, but controlled by LWEs running outside of it. This solution is optimal given the variety of possible execution contexts provided by user devices: from powerful workstations or laptops to tablets or smartphones, or even cell phones.

Moreover, a document-agent is the only communication interface, making MIND based platforms "technology neutral" and truly loosely coupled distributed systems, as is the case of classic email clients. This allowed us to free our solution from strong dependence on any programming language, ensure a stable migration mechanism for documents and relieve knowledge workers from being the underlying agent platform administrators. The only requirement needed to start our platform is the ability to configure a personal email client at each device willing to participate.

Acknowledgment This work was supported by the National Science Center grant no. DEC1-2011/01/B/ST6/06500.

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Improving Trace Analysis Using Ontologies for Hardware Resourcing

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Abstract

Testing is one of the traditional techniques used to verify the quality of complex systems. Traditionally, black-box testing relies on the degree of controllability and observability of the system under test; a system with increased controllability and observability is a system easier to test. One common observation point for testing is execution traces. Execution traces are sequences of events representing observation of the system under test. The execution traces are usually stored as plain text files (i.e., logs). The current size and complexity of systems makes the execution trace analysis a complex and time consuming task given the size and format of the information. This paper presents the application of ontological methods in facilitating execution trace analysis by defining an initial Execution Trace Ontology that is used by different ontology query tools. The queries used over the ontology allow us to identify errors presented in the execution trace associated with different aspects of the case study. Results showed the feasibility of this approach, where ontologies helped to provide semantics to the information and reasoning engines (ontology query engines), facilitating the definition of test goals.

Keywords

Execution trace ontologies • Software tracking • Trace analysis • Hardware resourcing

Introduction

Hypothesis

Using ontologies facilitates the analysis of trace information given the fact that trace information is provided as a flat flow of information. Ontologies have been used to interpret large sets of information and relations among these sets of data.

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Motivation

Understanding software behavior is a good way for tracking, testing, verifying and validating software applications. In this work we use trace analysis and ontologies to do hardware resourcing.

Hardware resourcing is a set of restrictions imposed to hardware Resources. This restrictions set must be satisfied under previously defined conditions set for the correct operation and performance of this hardware resource. The aim of this paper is to show how ontologies help to automatically do trace analysis in the context of traces.

Currently software applications are complex, with thousands of lines of code. Understanding how they work becomes a very hard task. If these applications have intensive interaction with hardware, this task becomes even harder, more complex and more time consuming. One of the best solutions to do this problem is implementing software

T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_79,

tracking to comprehend dynamic behavior. Software tracking refers to the set of activities and efforts to record aspects of a program such as input data, output results, variables states and behavior [1]. Traceability, and according to Schmauch Charles is the ability to show, at any time, where an item it, its status and where it has been [2]. Traceability is achieved by analyzing execution traces from a program or multiple programs. An Execution trace is a history record of a variable value, a pathway, an iteration number or event action, during the execution of a program.

Related Work

We reviewed previous work on execution trace analysis and the benefits of using ontologies in data analysis.

1. Execution Trace Analysis in Hardware Behavior: There are many examples in this area that make extensive use of execution traces analysis including I/O system behavior for high-end computing [3], distributing systems monitoring of workloads balance, fault-tolerance and communication over-heads [4], real-Time hardware debugging using instruction level execution trace and primitive instructions for control-flow analysis [5] and memory performance improvement and optimization with hybrid hardware/software traces [6]. The use of Trace analysis in Hardware is commonly used in hardware resourcing evaluation and testing.
2. Execution Trace Analysis for Security Control: Another area where execution trace analysis has been shown to be a good solution is security sensing and control. Some relevant research: A Model Checking Methodology for Cryptography Protocols Using Trace Generation and Analysis On-the-fly [7], Network Tine-tuning Applying Network Traces Analysis to Validate User Privacy and Anonymity in Wireless-network Communications [8], Packet-Level Trace Analysis to Identify Signatures and Verify Privacy and Security Concerns in P2P Traffic Identification [9].
3. Execution Trace Analysis for Performance Evaluation: Some examples of research in performance evaluation are: SCALASCA Performance Toolset Architecture to Analyze Parallel Application Performance via Event Tracing [12], SWARM a Tool to MapReduce Cloud Computing Application for Cloud Performance Tradeoffs Reasoning Using Statistical Workload Trace Analysis [13] and A comparative Failure Analysis of Diverse Distributed Systems via Failure Trace Analysis [10].
   These are three (3) areas where trace analysis was efficient and practical for behavior analysis; we think similar research in this areas will continue to expand.
4. Use of Ontologies in Data Analysis: Some research: Saccharomyces Genome Database (SGD) is a database that collects biological and chromosomal features of yeast Saccharomyces Cerevisiae using gene ontology (GO) and support annotations to make computational predictions giving valuable insight into this yeast [11]. SEGS and gSEGS are two semantic data mining systems used by Domain Ontologies to define hypothesis search spaces to process searching and evaluation [14]. Vaccine ontology (VO, http://www.violinet.org/vaccineontology) is an ontology used to model and mine vaccine candidates clinical trials and to mine vaccine literature [15]. CDAO (Comparative Data Analysis Ontology) is a biomedical ontology to represent data from evolutionary biology studies. It is more than mere taxonomy because it permit comparative data Analysis in this research field [16].

Debugging and Testing Complex Systems

Size, speed and complexity are major challenges to efficiently debug and test applications. To do these tasks we can use two principles for debugging and testing: Observability and Controllability. Observability is the ability of developers, debuggers and testers to trace data chains and to observe variable values in a set of variables which are observable (i.e. input and output variables) [17]. This property assists in understanding behavior and reducing complexity when we try to test or find bugs in software applications. Controllability enables us to modify values of variables by means of setting different initial values that can be modified in time (i.e. input variables) [17]. This property makes it possible to track and trace tasks and values. This job is called traceability.

Current applications are composed of several interacting components. Software development includes interactions among blocks of code with a specific task. These blocks can be internal, being part of software applications, or can be external (i.e. a class, library, module, etc.). Sometimes we receive source code (white box component), in other cases we receive only executable pieces of code (black box component). Comprehending operability in component interactions is too hard a task for large applications. To do these jobs more easily we can also use traceability.

Software testing and debugging use tracing as a technique to observe internal behaviors of the application. To implement traceability we use program traces; a trace is a history record of program activities during program execution. A tracing technique is a systematic method obtaining information from all traces recorded by an executed program. This refers to the retrieval of all historical information regarding input and output of variables and initial and final states of some of these variables. Logs (traces) of interacting applications are used as observation points.

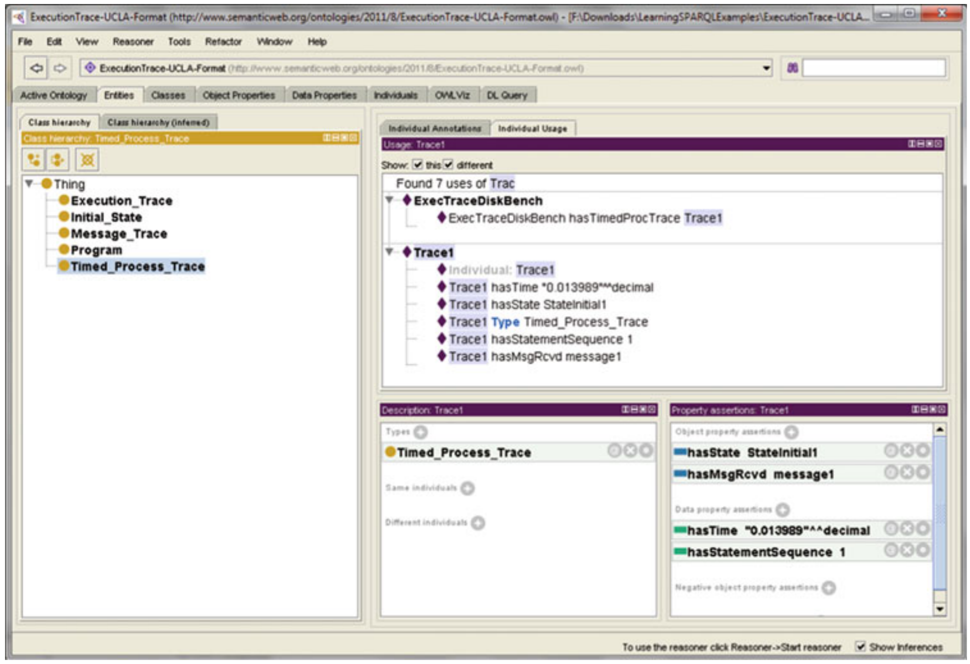

Fig. 1 pOETA ontology

An observation point is an observable code section performing tracing for testing, debugging or any other program behavior activity. Trace analysis consists of finding any explicit or hidden behavior that a trace set can contain.

Execution Traces

The Execution Trace of a program is the set of traces produced by the entire application. Following the UCLA Trace definition [18] each individual trace is named A Timed Process Trace and consist of a message trace, a timestamp and an initial state start it which is associated with an observation point.

In A Message Trace we can record all necessary information required to understand or track a task activity. Then execution trace makes possible to understand certain operations possible some operations and in this way predict future behavior.

Execution traces are samples of:

a. Record of program activities during its execution.
b. Program subroutine calls and variables status.
c. Set of activities and efforts recorded from inputs and outputs from program operations.
d. Timed record of Initial States, Messages and Timestamps. Nevertheless, analyzing and understanding behavior from a program's Execution Trace is a difficult hard task, requiring the creation of a model carry out this task. In the next section we address this problem.

Case Study

Problem Definition

The problem we address is detection of data transfer delays in a Video on Demand (VoD) application server. Delays in data transfer rate affect the quality of video displayed in VoD client applications.

We use VoD execution trace analysis to find and detect delays based on data transfer. By analyzing the traces we get data transfer rates.

An Execution Trace Ontology

We build an Execution Trace model in our pOETA (A particular Ontology for Execution Trace Analysis) Ontology following Execution Trace specification from UCLA University [18]. We make an instantiation of our model Ontology using this case study to show how it works.

We build pOETA Ontology following the UCLA definition, using Protégé to write it. Protégé is a free open source, Ontology editor and knowledge-based framework developed at Stanford University in collaboration with the University of Manchester.

pOETA implements an Execution Trace Ontology in which we populate Individuals of the program's execution trace into the classes (see Fig. 1). We have five (5) classes in which we can represent any Execution Trace generated by

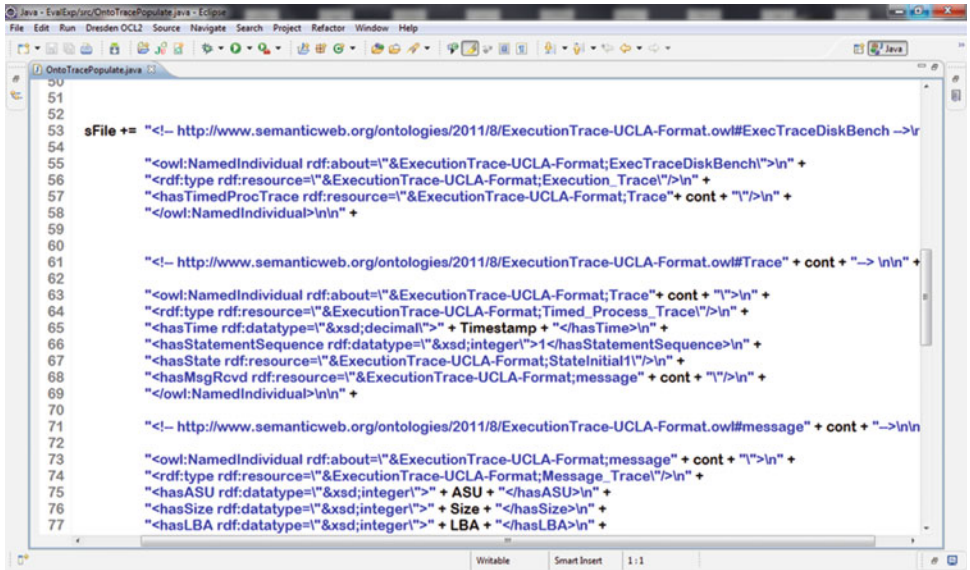

Fig. 2 Java app for XML/RDF code generation

any program. These traces can be a variable in length and represent as many program events as possible, and so shape the message trace string.

The Sample Execution Traces: Hard Disk Data Transfer

We populated the pOETA Ontology using (70,000) seventy thousand traces that were generated by a VoD server application. These traces were loaded into the message trace class and the timed process trace class. Because the task involving the loading of the traces was so intensive, we automated it by writing a Java program which generated all XML/RDF labels and appended them to our Ontology File (see Fig. 2).

The Ontology Query Tools

We use Pellet reasoner to check consistency in the populated Ontology. Pellet reasoner is an open-source Java based OWL DL reasoner developed by Clark & Parsia, LLC. After checking the ontology consistency and class relations, we write the query procedures to analyze traces in the Ontology.

The Execution Traces loaded into the pOETA Ontology were analyzed using SPARQL Query Language for XML/RDF files. SPARQL is a recursive acronym standing for SPARQL Protocol and RDF Query Language. SPARQL Query Language and SPARQL protocol are products of the W3C's RDF Data Access Working Group.

We prefer working with SPARQL, because using the Pellet reasoner is an intensive and time consuming process. In addition, SPARQL reduces the time in getting the query results, and writing SPARQL code make it faster and easier to develop robust queries.

Hardware Resourcing Analysis

Hardware Resourcing is a restrictions set that a Hardware Resource must satisfy under conditions previously defined for Hardware operation and performance.

For example, if we have a VoD application which needs a minimum data transfer rate to guarantee an acceptable quality of video display, we must probe by a measuring tests whether or not we are getting higher speeds, using data transfer history. This task is an example of Hardware Resourcing.

Hardware resourcing Analysis refers to measuring and evaluating the results obtained after submitting the data analysis of a specific Hardware resource.

Experimentation

We chose to track a Video on Demand (VoD) server because it is very intensive in its use of a Hard Disk server in satisfying a client's video request and generating a large quantity of execution traces, giving sufficient volume to be analyzed.

Case Study and Hardware Resource

A VoD application with hard disk communication is a good candidate for Hardware Resourcing. Maintaining a good video display is the main goal of this client service, because

Fig. 3 VoD disk server traffic traces sample

trace	ASU	LBA	Size	Opcode	Timestamp
:Trace1	0	614384	16384	"R"^^xsd:string	0.013989
:Trace2	0	20992320	8192	"R"^^xsd:string	0.021498
:Trace3	1	23522128	8192	"R"^^xsd:string	0.028998
:Trace4	0	614416	32768	"R"^^xsd:string	0.029566
:Trace5	1	11754208	8192	"R"^^xsd:string	0.042956
:Trace6	1	8602368	32768	"R"^^xsd:string	0.043402
:Trace7	1	8602432	8192	"R"^^xsd:string	0.043623
:Trace8	0	34311296	32768	"R"^^xsd:string	0.047005
:Trace9	2	20668192	8192	"R"^^xsd:string	0.047492
:Trace10	0	20992384	8192	"R"^^xsd:string	0.049704
:Trace11	0	614480	16384	"R"^^xsd:string	0.053753
:Trace12	0	22198016	8192	"R"^^xsd:string	0.057176
:Trace13	0	34311360	32768	"R"^^xsd:string	0.061543
:Trace14	1	11999088	8192	"R"^^xsd:string	0.064066
:Trace15	1	8602480	8192	"R"^^xsd:string	0.086993
:Trace16	0	30626016	8192	"R"^^xsd:string	0.094233
:Trace17	2	32233648	24576	"R"^^xsd:string	0.095143
:Trace18	0	33690624	24576	"R"^^xsd:string	0.103737
:Trace19	1	21553312	8192	"R"^^xsd:string	0.112883
:Trace20	2	30858816	8192	"R"^^xsd:string	0.11854
:Trace21	2	34543440	32768	"R"^^xsd:string	0.118868
:Trace22	1	8700496	16384	"R"^^xsd:string	0.123685
:Trace23	1	25290720	32768	"R"^^xsd:string	0.135333
:Trace24	1	8700528	32768	"R"^^xsd:string	0.137743
:Trace25	0	20993008	8192	"R"^^xsd:string	0.138051
:Trace26	0	33690672	32768	"R"^^xsd:string	0.138901
:Trace27	1	8602576	8192	"R"^^xsd:string	0.140519
:Trace28	1	13203184	8192	"R"^^xsd:string	0.145195
:Trace29	1	8602752	8192	"R"^^xsd:string	0.147802
:Trace30	1	25290784	32768	"R"^^xsd:string	0.149857

the bandwidth rate is critical in this type of application. Furthermore, the frequent and intensive access to Hard Disk server makes this environment ideal for testing and validating our Hardware Resourcing Analysis case study.

VoD applications have three domains: IPTV, Interactive VoD, and Teleconferencing. Each one has an specific bandwidth rate to meet a Quality of Service. In our case study we selected an IPTV (Internet Protocol Television) domain, even though of three domains are equivalent. For IPTV, a 512 kbps video rate requires a 614 kbps Bandwidth, a 1.5 Mbps video rate requires 1.8 Mbps Bandwidth, and a HDTV stream at 20 Mbps requires 24 Mbps Bandwidth (Video Rate demands 20 % more Bandwidth).

Data Inputs Sample Execution Traces

We use 70,000 (seventy thousand) traces recording data transfers for Read/Write from/to a Disk Server for a VoD application.

Each Trace is a data string containing the following information: Volume in Disk (ASU), Block Number (LBA), Size (in Bytes), Read/Write (Opcode), and Timestamp. (See Fig. 3).

Ontology Data Load and Representation

Using the pOETA Ontology (Fig. 1) and Java populate application we generate the same number of Individuals corresponding to the Message Trace class, the Timed Process Trace class and Initial State class (70,000 Individuals). After the pOETA Ontology was populated, we performed data Trace Analysis using SPARQL procedures. The results are in the next section.

Data Analysis and Queries

Trace analysis can be done using a string Logs analysis, but doing it in this manner is a difficult and complex task, because the Trace file is a plain text file without context. Using a pOETA Ontology we gave meaning to each trace data column. These traces can be reasoned using Pellet in Protégé, although this task was an intensive and time consuming process. To do this task more quickly and more flexibly we used SPARQL language. Using SPARQL procedures, we improved the speed of Trace Analysis, making it easier to create new queries from old ones.

Data Outputs: Answered Questions

Writing SPARQL procedures made it possible to generate different data profiles for the Traces. Having the Data correctly identified, it was possible to run Data analysis in different ways and to compare these results with previous ones. We were also able to probe whether or not Bandwidth restrictions were met.

Results

In order to analyze the loaded Execution Traces in the pOETA Ontology, we wrote SPARQL procedures running on an ARQ engine. ARQ is a query engine for Jena that supports SPARQL RDF Query Language. Jena is an open source RDF Framework for Java, developed by HP's Semantic Web program. SPARQL is a Query Language for RDF developed by the W3C Consortium. ARQ and Jena are integrated into the Joseki tool. Joseki is a Jena RDF Server including: The Joseki SPARQL Service processor, the ARQ engine and the Jena Framework.

SPARQL procedures read pOETA XML/RDF Individuals as Data Input and produce Output Data as Results of Queries. The use of Ontologies facilitate trace analysis because Ontologies give meaning to Flat traces, and organize and represent data relations inside trace messages. Analyzing Data traces is faster and easier, because using Ontology tools and The SPARQL RDF language makes it easier to create new queries from old ones (reuse), and with better Data Structures and Functions we can carry out more complex analysis. Ontologies interpret large sets of data and information easily. As a consequence, our queries working with seventy (70,000) thousand traces generate results in about 96 s.

Result Values Validation

After running the SPARQL Query we obtained the results shown in Fig. 4. The bandwidth transfer rate was 3,329,435 Bytes/s—over 26 Mbps. HDTV for IPTV requires 24 Mbps. With these results the Hard Disk Server for VoD TV has proved to generate good quality video for any VoD IPTV application.

Conclusions and Future Work

Conclusions

Through using Ontologies giving semantic structure to all data, and powerful tools like Pellet reasoner and SPARQL, Trace Analysis was highly improved. Using Flat Flow trace analysis is a complex, tedious, and excessively time consuming. Not Only is it necessary to identify all the information in each message trace, but it is also required that each and every analysis that needs to be performed be modelled by a data structure in a programming language. Ontologies give semantic structure to traces, by means of using a reasoner or an Ontology language. SPARQL language brings us advanced functions and data structures which create new Trace Analysis profiles easily. This is possible because Traces are consequently better organized, and make it easier to understand the trace classes and individuals relations in the ontology. Another advantage of Ontology trace analysis is that we can improve the speed of trace analysis significantly do to the fact that automatic analysis of trace analysis is faster with an ontology than with a flat trace.

Future Work

Some applications need to detect performance bottlenecks, programming bugs, malfunctions, and malicious activity among others things, in a post analysis Phase. This can be done by tracing relevant events, saving them, and then analyzing them in an off-line trace analysis or post-mortem trace analysis [19]. In future investigating project we have plan includes a case study using our pOETA Ontology to show that Ontologies can also improve post-mortem trace analysis. This paper discuses a Hardware Resourcing domain application. It is important to do further research in other execution trace domain areas, such us security, performance analysis, debugging, deadlock analysis or

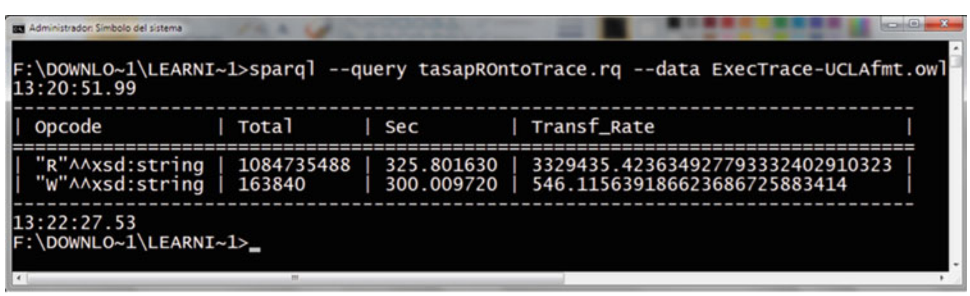

Fig. 4 Results bytes/s running the SPARQL query

off-line trace analysis and to study how ontologies work in these domains.

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An Energy Efficient Self-healing Mechanism for Long Life Wireless Sensor Networks

Dame Diongue and Ousmane Thiare

Abstract

In this paper, we provide an energy efficient self-healing mechanism for Wireless Sensor Networks. The proposed solution is based on our probabilistic sentinel scheme. To reduce energy consumption while maintaining good connectivity between sentinel nodes, we compose our solution on two main concepts, node adaptation and link adaptation. The first algorithm uses node adaptation technique and permits to distributively schedule nodes activities and select a minimum subset of active nodes (sentry) to monitor the interest region. And secondly, we introduce a link control algorithm to ensure better connectivity between sentinel nodes while avoiding outliers appearance. Without increasing control messages overhead, performances evaluations show that our solution is scalable with a steady energy consumption. Simulations carried out also show that the proposed mechanism ensures good connectivity between sentry nodes while considerably reducing the total energy spent.

Keywords

Wireless sensor networks • Self-healing • Energy efficiency • Node adaptation • Link adaptation

Introduction

Recent technological advances in microelectronics have favored the development of tiny and intelligent embedded devices called sensor nodes that can detect and send relevant informations related to a given environment. This has led to the emergence of a new technology, Wireless Sensor Networks. A typical Wireless Sensor Networks consists of a huge number of tiny sensor with sensing, processing and transmission capabilities [1]. These last decades, the wireless sensor technology holds the lead of the stage in several sectors such as environmental monitoring, military surveillance, medical diagnosis, building automation, industrial automation tasks, etc. In most cases, the area of interest (wireless sensor network's deployment area) is harsh or even impossible to access for human intervention. Therefore, the deployment is most often done by air plane dropping and this may often lead to unfair repartition of sensor nodes through the monitored region.

Beside problems related to random deployment, Wireless Sensor Networks are also suffering to many challenges such as data aggregation, routing, security, energy management, topology management, etc. The two later issues have attracted more and more interest from researchers and are addressed in this paper. Energy consumption and topology changes are of critical importance regarding Wireless Sensor Networks because the sensor node lifetime is closely related to its battery power and once deployed, they are usually inaccessible to be replaced nor recharged, due to harsh environment. However, the protocol designers should take

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_80,

into consideration these constraints and allow sensor nodes to have autonomy to self organize and covertly save their energy. In some types of applications, random deployment is most often used and it does not always guarantee better coverage and rational use of energy. This type of deployment, often causes energy or coverage hole problems due to unfair repartition of sensor nodes.

In this paper, we propose an energy efficient self-healing mechanism for wireless sensor networks. Our proposed mechanism use a combination of node adaptation and link adaptation techniques. The node adaptation technique consists of scheduling redundant nodes to take over sentinel nodes when they fall down. And the other one, link adaptation, is applied for connectivity check between sentinel nodes (active nodes).

The remainder of this paper is organized as follow. Section "Related Works", presents some related works in the literature. Section "Proposed Mechanism", details our proposed mechanism. Section "Simulations and Results" talks about simulation and experimental results. And finally, Section "Conclusion", presents our conclusion and future interested issues.

Related Works

A Wireless Sensor Network well-functioning strongly depends on:

- A good coverage of the interest area to retrieve relevant information
- A good connectivity between sensor nodes to better relay information toward the Sink node
- And also a good energy management policy for a long life network

However, the deployment strategies (deterministic or random) have a great influence on above criteria. Ideally, a deterministic deployment is desirable, but in most cases the monitored region, for example battle field, is inaccessible or dangerous for human access. Thus, a random deployment remains the only alternative way to monitor such regions. This deployment method often leads to collateral problems such as sparse or not at all covered areas. During the last decade, several works have been done in topology control issues. Solutions has been proposed in the literature in order to solve the related problems to the network topology changes. And these solutions can be classified according three approaches: node adaptation, link adaptation and mobility (mobile sensor node or robot) [2]. Node adaptation techniques are often based on clustering which propose the network to have an hierarchical organization, set cover computation which organize the network into multiple subset where each one can cover the whole network for a period of time and lastly node scheduling technics that relies on deploying redundant nodes and schedule their activities.

In [3], inspired by Ant Colony Optimization, authors propose an algorithm for set cover computation and selection. They propose finding maximum disjoint connected cover sets that satisfy network coverage and connectivity between nodes within a set cover. The ant pheromone is used as a metaphor for a search experience in cover sets reconstruction. Always in the same direction, Gupta et al. [4] use a node scheduling technique for topology healing and a probabilistic approach to determine the coverage redundancy degree. They schedule nodes activities to save energy and also ensure a better coverage. In [5], Corke et al. propose two algorithms. The first algorithm uses neighbor informations to detect failed nodes and determine hole location. The second algorithm uses routing informations to detect a hole from a distance and try to maintain the routing path. Their solution require that nodes keep state informations in memory.

Another approach in the literature is link adaptation based technic. Link adaptation is one of the common techniques used for topology control in Wireless Sensor Networks by adapting communication parameters and exchanging neighbor informations. As shown in [6], authors propose a self-healing framework based on link quality measurement to detect and solve coverage holes. They use dependency constraints through a three modules framework (Health Monitoring module, Self-healing Policy and Self-healing Engine). Li et al. [6] tune the received signal strength in order to maintain communication path and in the same way save energy when possible. In [7], the authors follow the same vein and propose a self-stabilizing algorithm for efficient topology control. They perform nodes' communication range adjustment by reducing when necessary the transmission power an build connected dominating set in order to establish efficient routing path. Cerulli et al. propose in [8] an appropriate set covers activation time scheduling. At every set cover construction, they make a procedure that select adjusted sensors and avoid banned other. They define banned sensors and exclude them in the set cover selection to avoid target lost.

Wang et al. [9] surveyed the mobility approach for topology healing in wireless sensor networks. Two main mobility strategies can be listed: mobility of sensor nodes [10–12] and the deployment of additional mobile robots [10]. Ghosh et al. show in [11] that Voronoi Diagrams can be used to detect and heal topology change problems like coverage or energy holes. Using the nodes' overlapping sensing range, authors propose a deterministic deployment of additional mobile nodes to maintain the network (coverage and connectivity maintenance). Authors in [12] follow in the same vein by providing additional mobile nodes to cover the holes. They define different roles assigned to the nodes and that role definition is based on node's residual energy and its location

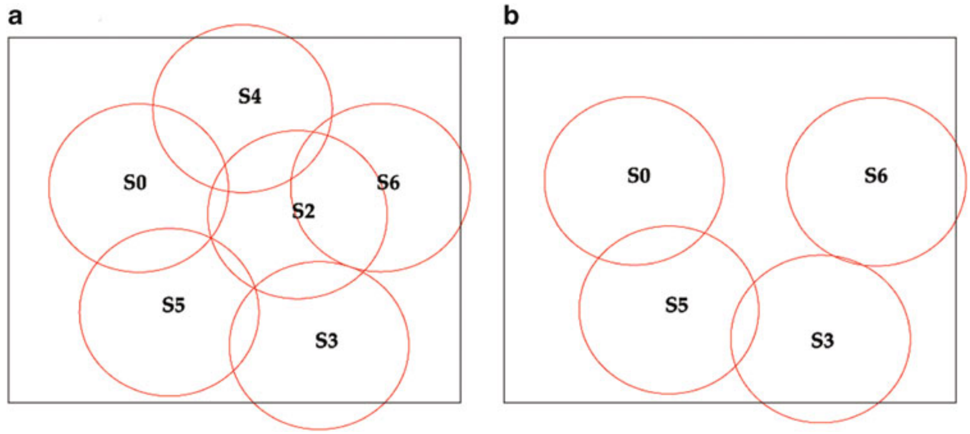

Fig. 1 Coverage loss and holes appearance

relatively to the hole. Then they propose an election method to guide the choice of the leader node which have the responsibility to interact with mobile nodes and designate when and where they should be deployed. Their solution does not take into account a sudden node failure in particular the leader node failure. If the leader node suddenly crash, the whole recovery process will be compromised. Bo-Ruei et al. [13] on their part, propose a dynamic multihop topology healing algorithm based on node mobility. Their algorithm is composed of two phases per round: construction and moving phases. The construction phase involves collecting neighborhood informations. This allows the nodes to have knowledge of the network topology from which they determine the target points. And then comes the moving phase which guide with precision (direction and distance) the movement of mobile nodes. This solution generates a lot of overhead with the exchanged neighbor informations. Wu et al. [14] make a deep analysis of energy hole problems and propose a distribute coronas based deployment to avoid energy holes.

In this paper, we opted for a scheduling based solution rather than deploying additional mobile nodes. Because energy is a scarce resource in Wireless Sensor Networks. However, mobility based solutions, in addition to the expensive costs of equipments, use GPS (Global Position System) and mobilizer components which are very energy intensive. And also, mobility is often not easy or not at all applicable to some regions because of their relief.

Proposed Mechanism

Problem Description

A sensor network should be autonomous for topology healing for two key reasons:

- The area of interest is often harshly or simply inaccessible.
- The lifetime of a node strongly depends on its battery which has a limit power.

Hence, Wireless Sensor Network protocol designers need to take into consideration mechanisms that would make autonomous networks in term of topology changes. In order to fulfill network surveillance functionalities, the sensor nodes must be organized to cover the whole monitored region. And the period of time that the network still satisfy this condition is generally defined as the network's lifetime. As a fundamental research issue, topology control is attracting more and more researchers. Wireless Sensor Networks are faced to several challenges such as coverage holes often caused by topology change or deployment. Topology changes in Wireless Sensor Networks may be caused either by energy depletion or by a key module failure (sensor unit, transmission unit, etc.). Without a coverage healing procedure, nodes failure can cause partial or total path loss toward the sink node or simply coverage holes (see example in Fig. 1). In this scenario, all the sentry are connected at time period t (Fig. 1a) and after a while, i.e. at time period $t + \Delta t$ sentry nodes *S4* and *S2* died, leaving their dedicated area blank (Fig. 1b). To solve this problem, protocol designer must take into account these eventual changes, by proposing distributed and dynamic energy efficient algorithm fitted for WSNs, to overcome these challenges. On our part, we propose an energy efficient self-healing mechanism for wireless sensor networks. Our solution combines two techniques, at different levels, (link and node adaptation) among those mentioned above. The link adaptation technic is applied to active nodes (sentry), this is to avoid coverage holes appearance between sentinel nodes, while node adaptation technic is applied to reserve nodes (redundant nodes subject to pass occasionally into probing mode).

Energy Efficient Design

In this paper, we propose an energy efficient topology healing mechanism based on a probabilistic model and nodes redundancy. We choose to deploy in the area of interest a

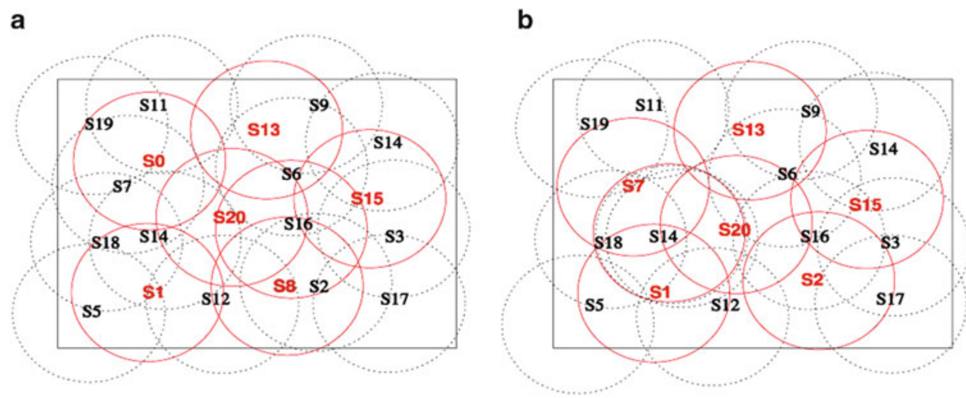

Fig. 2 Hole healing with redundant nodes

huge number of sensor nodes such a way to create a high redundancy. And each sensor node had sufficient autonomy to compute and control it sleep and wake up phases. At the deployment, all sensor nodes are initially in sleep mode and that for a Weibull distribution time [15]. When they wake up, nodes will compete with the neighborhood to choose a sentinel which will be responsible for the monitoring. When a node wakes up, it probe its neighborhood to look for a standing sentinel. If it is aware that there is no guard present in the vicinity, it immediately stands guard (gets a sentinel role) and monitors the dedicated area. Else, it updates its probe rate for a new sleep time computation and then goes back to sleep mode.

Hole Healing Through Link Adaptation

Due to the nature of the carrier, collisions may disrupt wireless sensor nodes' communications. Therefore, nodes can wake up and start guard, after probing, believing that there is no sentinel node in its vicinity. This may results to a duplicated monitoring in a given region. To avoid this energy waste, we have chosen in this work to combine node adaptation technic [15] with link adaptation one. Here, the link adaptation technique allow us to dynamically adjust a sentinel node's communication parameters. As shown in *Algorithm 1*, sentinel nodes use connectivity message to evaluate the link quality between them. Thus, each sentinel node randomly shot a timer and when it expires, it sends connectivity message to other sentinel nodes. And so, when they receive the message, they send back a reply. The sentinel node which initiated the dialogue, measure the link quality based on the obtained LQI[1] [16, 17]. If the measured LQI value is below to a given threshold, node will adjust its communication power strength in the aim to maintain a good connectivity with other sentinel nodes. Otherwise, it ignores the message and prepares itself for another connectivity check round.

[1] Link Quality Indication—CC2420.

Algorithm 1 Holes healing using active nodes (Connectivity adjustment between sentinel nodes)

$t_c \neq 0$, $linkState = \{strong, weak\}$
$status = ACTIVE$, $connMsg = FALSE$
if (t_c *expires*) **then**
  Send connectivity msg
  if ($connMsg$) **then**
    Check linkrobustness(LQI) from received msg
    if ($linkState == strong$) **then**
      Set timer t_c
    else
      Adjusts link parameters
      Set timer t_c
    end if
  end if
end if

Hole Healing Through Node Adaptation

In this paper we propose a dynamic and distributed topology healing mechanism. Our approach enable nodes to have sufficient autonomy to control the network topology by having a dynamic and distributed holes detection. Nodes have complete control over when they go to sleep or not. For this, we consider a sufficiently dense network and we propose to exploit nodes redundancy on the one hand extend network lifetime and on the other hand compensate coverage holes often due to node failures. Our hole healing scheme operate at two levels: coverage recovery by reserve nodes and connectivity adjustment by sentinel nodes. The reserve nodes (redundant nodes) sleep most over the time to save their energy. But, they often wake up, according to a Weibull sleep time computation, to probe their neighborhood (refer to the *Algorithm 2*.). The probing phase permits, when the neighboring sentinel falls down, that a reserve node detect this failure and wakes up to take it over for the monitoring task. The scenario in Fig. 2 is an illustration example. At the period *t*, the subset of sentinel nodes is composed by *S0, S1, S8, S13, S15* and *S20*. After a while, nodes *S0* and *S8* fall down and then, the reserve nodes *S2* and *S7*, during their probing phase detect the problem and wake up to maintain the topology. Thus, at time period $t + \Delta t$, we have *S1, S2, S7, S13, S15* and *S20* in guard as sentinel nodes.

Algorithm 2 *Hole maintenance using redundant nodes (nodes switching between sleep and probing mode looking for on guard sentinel neighbor). status is a node's mode;* t_s*,sleep time;* t_w*, wait for neighbor response time;* λ*, Weibull scale parameter;* β*, Weibull shape parameter*

$status = SLEEP, rcvMsg = FALSE$
$t_s > 0,\ \lambda > 0,\ t_w > 0$
if (t_s *expires*) **then**
  $status = PROBE$
  probe neighborhood
  set timer t_w
  if (t_w *expires*) **then**
    if ($rcvMsg$) **then**
      $R = uniform(0, 1)$
      $t_s = \frac{1}{\lambda} log\left(\frac{1}{R}\right)^{\frac{1}{\beta}}$
      $\lambda(t) = (\beta \times \lambda) \times (t \times \lambda)^{\beta - 1}$
      $status = SLEEP$
      set timer t_s
    else
      $status = ACTIVE$
      generate random timer for
      connectivity check t_c
    end if
  end if
end if

Table 1 Simulation parameters

Field	100 × 100 m
Number of nodes	[50:1,000]
Deployment type	Uniform
Environment	Noisy
Nodes' transmission power	−5 dBm, −10 dBm
LQI threshold	7

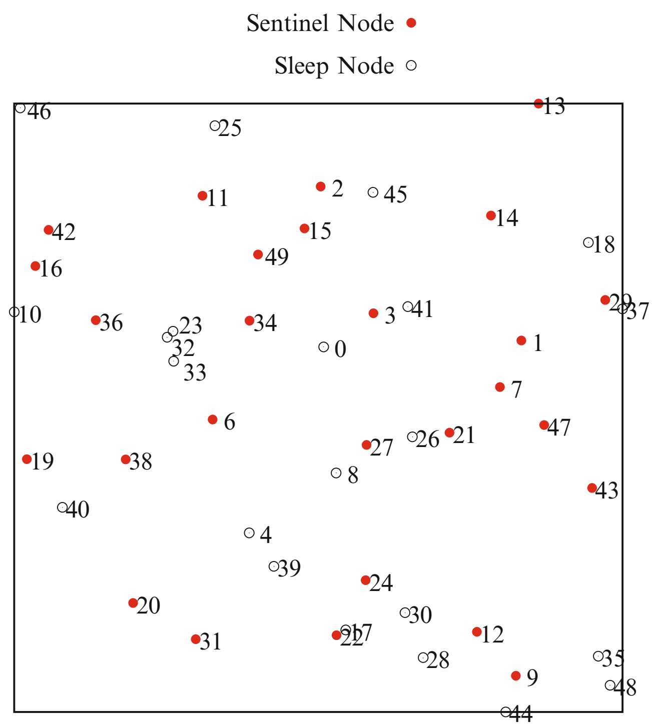

Fig. 3 Hot network snapshot with 50 randomly deployed nodes

Simulations and Results

To evaluate our proposed solution's performance, simulations are carried out using Castalia [18], an OMNeT ++ [19] framework dedicated to Wireless Sensor Networks (WSNs) and Body Area Networks (BANs). We checked expected improvement of our solution by comparing it to our previous works in [15].

Simulation Setup

Simulations are performed in an interest area of $100 \times 100\ m^2$ with a number randomly deployed nodes from 50 to 1,000. The simulation parameters details are summarized in Table 1.

Results and Discussions

This work focus on self-healing solution for Wireless Sensor Networks by emphasizing the energy efficiency and strong connectivity between sentry.

1. *Reliable sentry connectivity:* To maintain strong connectivity between sentinel nodes, the *Algorithm 1* performs link quality detection in aim to avoid sentinel outlier appearance. We include link quality check when exchanging probe messages. That is say, if a sentinel node receives a probe response message, it check the LQI value and compares it with a desired one. When it detects a weak link *i.e.* LQI test fails, it adjusts its transmission power from −10 to −5 dBm. And Fig. 3 can illustrate the obtained connectivity between sentry nodes.
2. *Energy efficiency:* The average energy spent is measured under two scenario:

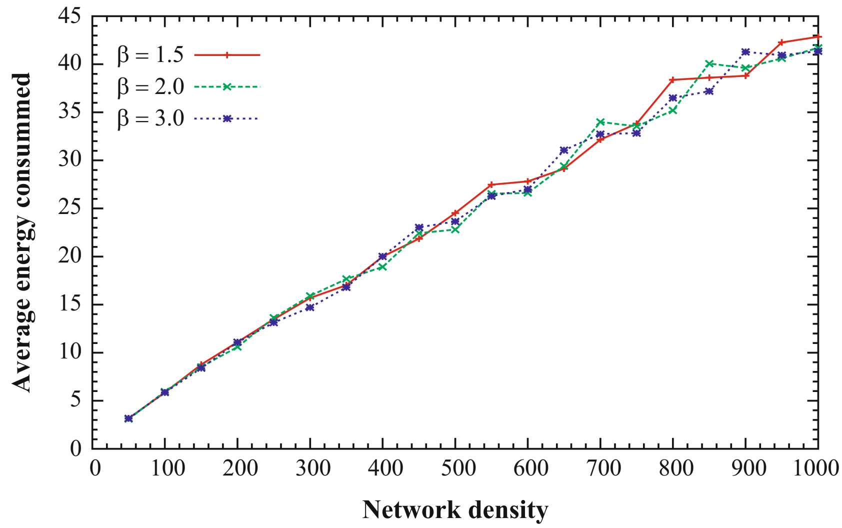

Fig. 4 Average energy consumption by varying the β parameter

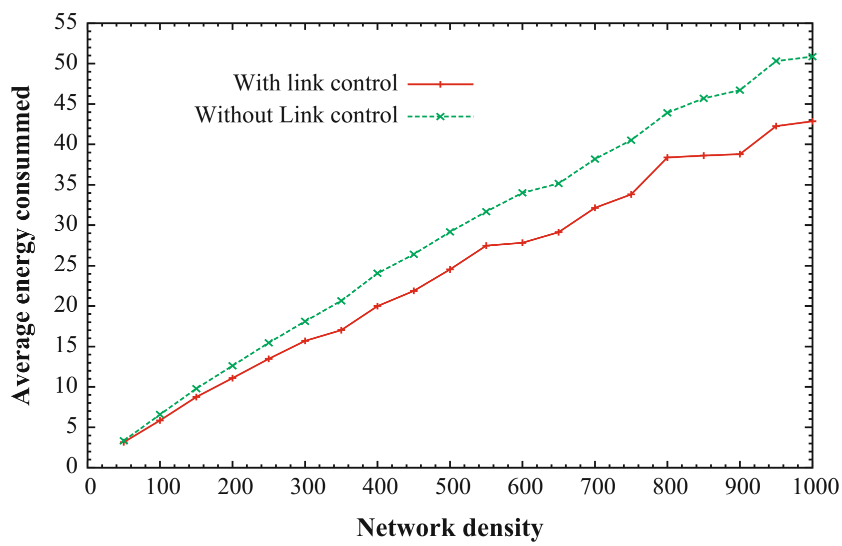

Fig. 5 Average energy consumption for sentinel scheme: link control vs. no link control

- Average energy consumption by varying the Weibull shape parameter β. We recall that our sentinel scheme uses the Weibull probabilistic distribution to calculate reserved nodes wake up times and also to update their probe rates. Curves in Fig. 4 show that, with the enhancement introduced here, the energy consumption is not affected when varying the β parameter. This shows that our mechanism provides an almost steady energy consumption compared to other probability distributions, variant of the Weibull probability distribution, such as Rayleigh when $\beta = 2$.
- Curves in Fig. 5 show total energy consumption of the whole network after 1,000 s of simulation time. We note that our algorithm, upon maintaining sentry connectivity, considerably reduce the average energy consumption. This can be justified by the fact that we opted to include the link control step in the probing downward phase. This is to say that, the link control algorithm is called when sentry node receive probe response from others sentry. This permits by reducing control overhead (reduce in the same time transmissions between sentry nodes) to considerably improve energy consumption.

Another advantage of our solution is that it supports the network scalability without a remarkable impact in the total consumed energy.

Conclusion

In this paper, we focus on topology healing solutions through distribute sleep scheduling. We propose an energy efficient self-healing mechanism designed to scheduling sensor nodes activities and also prune duplicated sentinel nodes for a single area monitoring. Performances evaluation show that our proposed solution performs strong connectivity between sentry node, permits a flexible and efficient energy usage and finally it supports the network scalability.

Future works will targeted the robustness of our scheme against security attacks like DoS (Deny of Service) or Deny of Sleep attack in Wireless Sensor Networks.

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Novel Steganography over HTML Code

Ammar Odeh, Khaled Elleithy, Miad Faezipour, and Eman Abdelfattah

Abstract

Different security strategies have been developed to protect the transfer of information between users. This has become especially important after the tremendous growth of internet use. Encryption techniques convert readable data into a ciphered form. Other techniques hide the message in another file, and some powerful techniques combine hiding and encryption concepts. In this paper, a new security algorithm is presented by using Steganography over HTML pages. Hiding the information inside Html page code comments and employing encryption, can enhance the possibility to discover the hidden data. The proposed algorithm applies some statistical concepts to create a frequency array to determine the occurrence frequency of each character. The encryption step depends on two simple logical operations to change the data form to increase the complexity of the hiding process. The last step is to embed the encrypted data as comments inside the HTML page. This new algorithm comes with many advantages, such as generality, applicability to different spoken languages, and can be extended to other Web programming pages such as XML, ASP.

Keyword

Steganography • Carrier file • Encryption • HTML code

Introduction

The rapid growth of the Internet has led to the increasing demand for security mechanisms to facilities the transformation of sensitive information through different networks. Since the Internet is a public media used to transfer information between different parties [1], hackers can exploit the messages' contents between communicating parties. On the other hand, different methods have been developed to prohibit an attempt to break or expose actual messages. Encryption algorithms reported in literature protect sensitive information by converting plaintext into ciphertext. Modern encryption algorithms depend on sophisticated mathematical operations to change the information form. Other techniques depend on concealing the message existence, which is called Steganography [2]. As Fig. 1 shows, Steganography consists of three main components; embedding algorithm, carrier file and the hidden message.

The carrier file plays an important role in designing steganography algorithms. Image, audio, video, and text are different media used frequently over the Internet [3]. Each of these carrier files types has certain characteristics that enable the user to insert the data inside. Image files are the most widely used files as carrier files which contain high ratio of data frequency [4]. On the other hand, it is not easy to use the same image to hide different messages, since comparing similar images may allow attackers to expose the concealed data. Audio files are represented as sine or cosine waves. Some techniques suggest to shift the phase to hide zero's and one's [5]. Text files represent the most

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DOI 10.1007/978-3-319-06773-5_81,

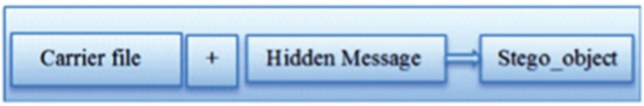

Fig. 1 Embedding algorithm

difficult carrier files, since text files contain little redundant data compared to other carriers [6].

Text Steganography is classified into different categories. One of the most popular text Steganography methods is semantic Steganography [7]. This technique makes use of synonyms in the same language or similar languages such as American English and British English. This is done by creating a dictionary of synonyms and exchanging words to pass zero or one. Other categories hide data depending on the language syntax. This is known as the earliest techniques that employ the physical format of text to conceal information. Other scenarios employ linguistic properties to hide data and depend on the file generation to convey the information [8].

In section “Prior Works” of this paper, prior work is presented and compared. The proposed algorithm is discussed in section “Proposed Algorithm”. Experimentation and results are demonstrated in section “Experiments and Results” The algorithm is analyzed in section “Algorithm Analysis”. Finally, section “Conclusion” offers conclusions.

Prior Works

HTML or Hyper Text Markup Language is the basic programming language for web pages, which can be combined with other languages such as Macromedia Flash and Java Script for animation goals [9]. Moreover, HTML does not need special software for programming. Most of the new web programming languages are based on HTML concepts. Generally, HTML is used to create the static part of websites. HTML code consists of two parts; (1) tag which is surrounded by angle parentheses (< >), and (2) the information between tags. Internet browsers only display the content without tags, since tags control the appearance of the web page content. Tags order the page organization and design, and are not-case sensitive.

HTML represents the source code of a web page. However, Internet users are only concerned about the web-page information. Based on this hypothesis, most Steganography algorithms over web pages deal with the coding of the web page and not the page’s information.

In [10], a text Steganography was presented by using HTML files. Authors classified HTML into two categories; primary attributes and secondary attributes. If a secondary attribute is followed by a primary attribute, then a 0 bit is detected, else a 1 is detected. The authors suggested applying two steps. The first step is encryption to improve the message security. The second step suggests applying HTML Steganography scenarios to hide the bits. The HTML Steganography algorithm consists of three main steps. The first step is the scanning process to search all tags in the web page to classify them into two categories; primary attributes and secondary attributes. After the analysis, the hidden bit is read from the hidden file. If the hidden bit is 1, the primary and secondary consecutive attributes are swapped, otherwise no change is applied. The main advantages of this algorithm are that it can be applied in different languages without any change in the file format or size. All the changes in the code file result in no effect in the web information. In addition, many web page contain a lot of information that are publicly available and coded in HTML. Moreover, most of the new versions of web programming languages apply the same HTML concepts where all of them use tags.

Most programming languages improve their readability and code documentation using non-compile notes called comments [11]. Usually HTML files support this property by adding “<! – –”at the beginning of the comment and “– –>” at the end of the comment. Comments do not appear in the Internet browser, so Internet users are unaware of any changes in the website appearance because of the comments. This implies that huge amount of data can be inserted inside the web page without being noticed by the users. In addition, comments can be added in any location inside the file.

The main advantage of this method is that huge amount of data can be inserted in the carrier file, and the hidden data can be inserted anywhere in the HTML document. Hidden data are readable; however, Internet users generally do not explore the page code. Only the programmer is concerned about the comments to understand the programming methods.

In [12, 13], other HTML Steganography algorithms were presented by using one of the HTML characteristics, changing tag letter cases to hide data. In these algorithms, uppercase would correspond to 1 and lowercase is 0. This is while there is no difference between upper and lower case letters in the HTML code for web page viewers. The advantages of this method are similar to other methods where hidden data do not appear in the web browser. Moreover, huge amount of data can be hidden inside the HTML files. On the other hand, printing the file will, however, remove the hidden data.

Other HTML algorithms were proposed that suggested using HTML tags, and employ some varying combination or gaps to hide data [13]. An example is as follows:

< img > < /img > hide 0
< img/ > hide 1

By using this method, each tag can pass bits by adding “\” to the end of tag. The main point of this method is the non-suspicious property, as “/” is usually used in most HTML tags.

The End of HTML file is also used to hide data. HTML files usually start with < html > and end with </html > [14]. One of the simplest methods is to hide data inside HTML by inserting the whole hidden data after closing the HTML file </html>. This way, data will not appear in the browser output, and the whole hidden data can be read from the end of the HTML file.

In [14], a technique was introduced that suggested using one of the HTML properties; employing HTML attributes, where each tag on the HTML page is the ID attribute. The file is usually compressed to reduce the memory space. Each tag ID consists of three parts; the object name, the title of the HTML page, and four coded characters. By employing some bytes from the ID attribute, 2 bytes can be hidden. The main advantage of the ID attribute algorithm is the large number of HTML files over the Internet. Moreover ID attribute is a common way used to compress HTML files. This method can also be applied on other web design languages such as XML and ASP.

Proposed Algorithm

In this paper, we employ cryptography and steganography techniques to pass secure information. Since web pages are used as the carrier for data, and since the pages are published over the Internet, authenticated users can access the hidden data. The proposed algorithm consists of three main steps as shown in Fig. 2, where the first and third step represent inverse operations.

The Conceal operation consists of the six steps:

1. Statistical Operation:
   (i) This step creates an array of 26 elements to count the characters' frequency. The frequency array can be extended or shrunk depending on the language used in the web page. Our experiments are applied to the English language
2. Character representation:
   (i) After the frequency array has been generated, the lowest two characters in frequency can be represented by one bit. If the two characters have the same frequency number, the character order specifies which one is zero. For example, if letters X and Z appear ten and six times, then Z can be represented by 0 and X by 1. Moreover, if both letters have the same occurrence number, then X is represented by 0 and Z is represented by 1. Similarly, the next four characters can be represented by two bits, and so on.
3. Embedding process:
   (i) In this step, the secret bits embedded after the character representation is 8 bits. In other words, if the first character representation is 0 and hidden information is 0111011, the code will be 00111011.
4. Encryption process:
   (i) This step consists of three simple binary operations. The binary representation is first complemented then exclusive OR (XOR) is performed with the key. Output of XOR gate shift left by one bit and again enter to XOR as input. On the other hand, the key creation depends on the page index where each page has rear index. This operation is repeated twice as shown in Fig. 3.

The following is a numerical example where the input is (C) 01000011 and the key is 10001100:

Step 1: Binary representation for C = > 01000011
Step 2: 1's complement of C = > 10111100
Step 3: 10001100 XOR 10111100= > 00110000
Step 4: Shift left 00110000 = > 01100000
Step 5: 10001100 XOR 01100000= > 11101100
Step 6: Shift left 11101100= > 11011001

1. Decoding Process (convert binary code to ASCII code).
   i. The next step after embedding is decoding to convert the binary code to text form. In the running example, 11011001are decoded to (Ù).
2. Insertion Operation:
   i. The last step in our algorithm is the insertion operation where the output of step 5 is inserted into the web page web page code as a comment. The comments do not appear in the page output view.

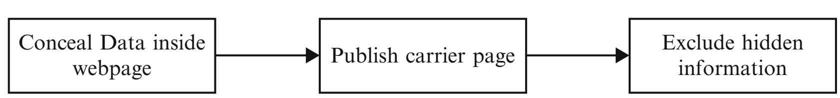

Fig. 2 Steganography process

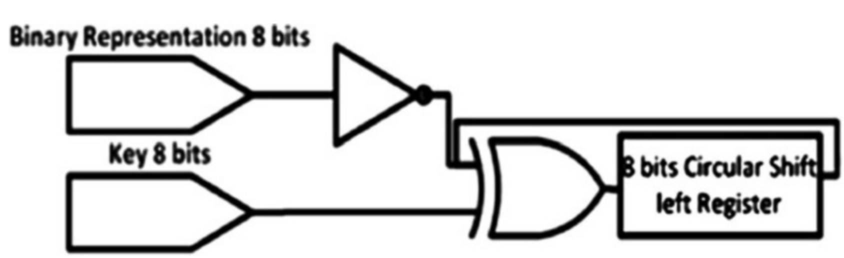

Fig. 3 Encryption gates

At the other end, the user can exclude the hidden information by the following procedure:-

1. Statistical operation:
   This is the same first step in the conceal operation
2. Reading comments:
   The next step is to read comments from the web page.
3. Encoding process:
   This step converts the comments from text into binary representation.
4. Decryption process:
   This step is similar to the encryption process with the same number of iterations.
5. Exclude character code representation:
   This step is performed by using the Frequency array created in step 1, and comparing it with the binary output of step 5. The embedded information is acquired by removing the character representation.

Experiments and Results

In this section, we explore some of the results acquired by applying our algorithm and considering the concept of hidden ratio.

Figure 4 shows some experiments of different websites and the corresponding statistical information for the visited websites.

$$\begin{aligned} \mathit{letter\ Freq} = {} & \mathrm{LEN}(\mathrm{website}) \\ & - \mathrm{LEN}(\mathrm{SUBSTITUTE}(\mathrm{website},\ \mathrm{letter},)) \end{aligned} \tag{1}$$

The number of hidden bits is 122 bits regardless of the website size. On the other hand the suggested algorithm applied non pure Steganography by employing encryption gates to improve the system transparency, which increases the complexity to identify the message content. In addition, the statistical equation improves system robustness, and this avoids ability to change the sensitive message during transformation process.

Algorithm Analysis

Our proposed algorithm has a number of advantages over other algorithms. This section explores some of its benefits.

1. Language independency: The suggested algorithm can be applied to any language. This enables users to employ it regardless of the language used in the web page. Different languages will have different frequency array size. For example, if the web page contains Arabic letters then the array size is 28, and if English text, the array size is 26.
2. Algorithm transparency: One of the most important criteria to measure the performance of a Steganography algorithm is the ability to avoid suspicion. This algorithm improves the transparency feature by hiding data inside the code, where the hidden data are also encrypted. In addition, the embedded bits are inserted as comments, and the comments do not appear in the web page output. The proposed technique also avoids changing the file format to reduce intruder suspicion.
3. Hidden ratio capacity: The presented algorithm hides different amount of bits inside each web page. For example, if we assume the web page has English text, at most 126 bits can be hidden in each page.
4. Algorithm reusability: The presented algorithm enables the user to create his/her own web page or reuse same web page to hide different messages.
5. Algorithm robustness: The proposed algorithm prohibited any change for carrier page code during the transmission process, as the hidden data are stored in the page code as comments.

Conclusion

Different algorithms have been presented to hide data inside text files. Some of these methods were designed to be applied in specific languages, while others can be applied regardless of the language. In this paper, we presented a

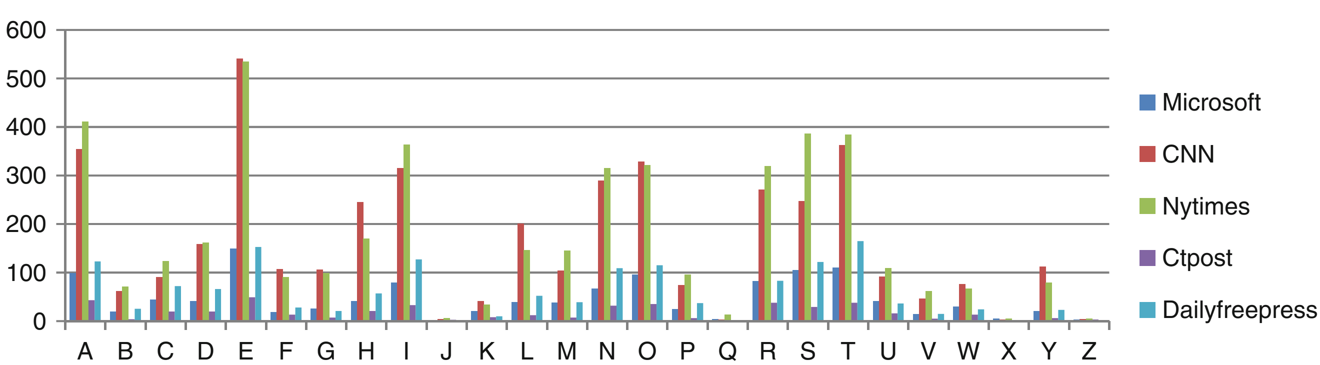

Fig. 4 Letter frequency

promising algorithm that can be applied to different languages over HTML pages. The proposed algorithm offers high hidden capacity compared to other algorithms. In addition, the algorithm offers robustness, as the hidden data was inserted inside the page as comments, and the Internet browser does not show it. Moreover, the algorithm enhances transparency by using an encryption mechanism.

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Secure Cost Effective M-Learning Through Cloud Computing

K. Kartheeban and M. Venkatesulu

Abstract

Mobile learning (m-learning) has been realized as an efficient tool which has potential to enhance and support the traditional way of learning. However, due to increasing number of users, services, education contents and resources, how to deploy m-learning become problematic. There are many aspects for e-learning. Some of them are providing study materials, teacher student interaction, and timely distribution of information etc. Providing virtual classrooms with the help of multimedia technology is an advanced method in e-learning. In the area of e-learning an efficient way to provide effective e-learning service is through delivering video and audio contents online. The recent technologies like screen casting is an example to show how effective they are. The learning information such as video and audio of institution/individuals is an important asset. It means that the e-learning video and audio content should be protected in motion, in process and at rest when internet based e-learning system is used. Encrypt the data wherever it is in the cloud: at rest, in process, or in motion. Data doesn't stay in one place on any network and this is especially true in case of data in the cloud based m-earning. Cloud computing is a promising technology to overcome the problems in m-learning and it provides reliable, customized and dynamic computing environments for end-users. In this paper we present a new and simple cost effective encryption algorithm (MBBXOR) as selective encryption for secure storing mobile distance learning content and streaming it in an extended cloud computing environment.

Keywords

Cloud Computing • Security • Cryptography • Access Control • Video/Audio streaming • MBBXOR

Introduction

Education is an important component in almost every one's life. Generally, today's world there are lot of methods for gaining knowledge or learn something. One of the most promising methods is orthodox education systems and now days this is not suitable to catch up with the changes of learning demand in time. The second promising method uses high performance computing, and networks have brought opportunities for these alteration in the current system of learning. These methods of learning are associated with e-learning. E-learning is commonly referred to the intentional use of networked information and communications technology (ICT) in teaching and learning. E-learning services can be divided in to Synchronous and Asynchronous e-learning services [10]. In synchronous e-learning system the students need to be online at predefined time. Asynchronous e-learning service can be accessed by the students whenever they want. There are many benefits of e-learning over orthodox learning and are listed below.

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DOI 10.1007/978-3-319-06773-5_82,

Advantages of E-learning

The growth of the World Wide Web, high-capacity corporate networks, and high-speed desktop computers will make learning available to people 24 h a day, seven days a week around the globe. This will enable businesses to distribute training and critical information to multiple locations easily and conveniently. It means that the student/employees can then access training when it is convenient for them, at home or in the office. Cloud has many advantages such as it ensures substantial cost savings due to elimination of travel expenses, Just-in-time access to timely information, improved collaboration and interactivity among students and online training is less intimidating than instructor-led courses.

Drawbacks of E-learning

However, the system setup and maintenance for traditional web based learning environment requires a lot of investment, but without any returns much. It does have some limitations, such as up-front investment, technology issues, in-appropriate content, and cultural acceptance.

Need for Mobile Cloud computing

Due to this, almost all educational institutions are forced to find ways to offer rich, affordable services and tools for education. And also now a day's youth are brought up in a world very different from that of their teachers or parents. They very much like to use mobile phone for almost all purposes. Currently, there are two emerging paradigms in Information and Communication Technologies (ICT) and all the community including students wants to make use these two emerging paradigms for all purposes in their life. The first one is the—anytime, anywhere, on-the-move paradigm, to be called the mobility paradigm, and the second one is the cloud computing paradigm. Both paradigms are used to communicate, access and utilize information resources, and connect with peers and colleagues, thus affecting all aspects of our lives including education or learning such as Personalized learning, Collaborative learning, Project-based learning, gaming, shopping, banking, health care etc. These technologies allows users to carry large number of resources in their packet and access them at anytime, anywhere and by using any portable devices such as smart phones, hand-held devices with internet connections.

The fast growing Mobile learning is now part of a new learning landscape created by the availability of technologies supporting flexible, accessible, personalized education. Learners' everyday uses of mobile phones and other devices such as games consoles, which can also be used for learning, are now major drivers for the rapid uptake of mobile learning throughout the world. Crucially, mobile learning can contribute to the global community by providing quality education for children, youth and adults. Mobile learning (or m-Learning) comprises any kind of learning which is done on mobile and handheld gadgets either in or out of class, or learning which takes place 'on the go', as part of class time, or outside. Although mobile learning is often taken to be synonymous with the use of mobile phones, it is increasingly associated with other devices such as tablet computers, portable games machines, mp3 players, ebook readers and other devices which allow people to continue more traditional approaches to learning as they move through their daily lives. As such it fits comfortably into definitions of blended learning. Mobile learning is known by many different names, such as mLearning, uLearning, personalized learning, learning while mobile, ubiquitous learning, anytime/anywhere learning, on-the-go learning and handheld learning. No matter what you may call it, mobile learning is an invaluable tool accomplishing recent trends in education. But however mobile learning systems usually require many hardware and software resources. There are numerous educational institutions that cannot afford such investments, and cloud computing is the best solution for them. The main advantage of the cloud computing is that it has centralizing storage, memory, processing, bandwidth and also it reduces the cost effectiveness for the implementation of the Hardware, software and License for all. This paper describes both synchronous and asynchronous e-learning system. During synchronous e-learning the students must be present at the class time to get the streaming video tutorial online. Video on demand is one of the advancements in the area of multimedia service using which user can select and view the selected video [11]. Examples of applications of video on demand are movies on Demand, E-Ecommerce, Interactive advertisement etc. and there are three types of playing methods in e-learning. They are download mode, streaming and progressive download or pseudo streaming. In download mode the downloaded video is played only after the complete download of the video. In Streaming mode the video is downloaded in parts and each part is decoded and played before the complete video is downloaded. In progressive download the video is downloaded as in download mode but the user can play the video if the download speed is sufficiently greater than the playing rate. Main issues in video on demand service are providing sufficient bandwidth with low cost and security of video content [12]. There are many technologies that can be used to provide e-learning video on demand through internet. They can be traditional web based technology, grid technology and cloud technology. Connecting and integrating ideal system resources with the application of proper operating system and software are called grid computing technology. By using this technique collection of sufficient computing power for a super computer is generated. Providing computational power to a remote place through a tcp/ip network such as internet is called cloud computing [13]. The main features of cloud computing are location independent access, competitively low deployment cost, scalability and providing required bandwidth during streaming e-learning content etc. So the cloud computing provides an effective system for providing e-learning video on demand and it overcomes all the problems of e-learning with mobile.

Cloud computing is growing rapidly, with applications in almost any area, including education. Cloud computing is an Internet-based computing paradigm, with its built-in elasticity and scalability, for delivering on-demand computing services to its users in a pay-per-use basis, in a similar fashion as already done for other common utilities like water and electricity. It marks the reversal of a long-standing trend, where end users and organizations are now willing to surrender a large measure of control to 3rd-party service providers [2]. Cloud computing provides its users a power of choice among less expensive (or free) competing services that are user-friendly and more reliable with a tremendous advantages in terms of mobility, accessibility, and collaboration, allowing users, at any location, to use any device, such as a PC, or a mobile phone, etc. [3, 2]. The use of cloud computing will have a profound positive impact on the cost structure, with its dynamic re-arrangement, eliminating some of the expenditures and reducing others, to lower the total cost of ownership (TCO) of IT resources [2], on all industries using IT resources. This results in an indirect impact on business creation by reducing barriers for entry and enabling quick growth, and the macroeconomic performance at national levels [4], extending to a global level. The combination of mobile devices and wireless communication offers huge potential for distance learning, assuming how acquainted most of the young students are with these mobile technologies. As we move these applications from the desktop to more universal and increasingly powerful mobile devices, we could simply move existing tools to new emerging platforms [1]. Though these advantages are available by using portable devices, there are some challenges such as bandwidth, security, timing, storage and quality of service by using cloud computing for m-learning.

Challenges

There are several major challenges in providing an internet based multimedia e-learning system. The main problems in internet based multimedia e-learning are bandwidth, security, timing, quality of service and storage. But if we go for cloud based system these issues will get solved as cloud service providers provide bandwidth auto scaling and etc. For example the bandwidth facility provided by the cloud provider analyzes the traffic history and provides required amount of resources. This provides better quality of service at the same time low cost for bandwidth [10].

The rest of the paper is organized as follows: The literature review/Related work is presented in Section "Related Work", followed by applying MBBXOR Encryption Algorithm in selective mode is in Section "Proposed Work". Section "Experimental Evaluation and Security Analysis" presents experimental evaluation and Section "Conclusion" concludes the paper.

Related Work

Cloud computing in mobile platforms has invoked a new wave of evolution in the rapidly developing mobile world. Many mobile devices such as smart phones, PDAs, tablets, pockets PC have been added to the Mobile Cloud Computing (MCC) Environment. Mobile Distance Learning is seen as one of the potential future applications of MCC [5, 6]. Mobile Learning (m-learning) is one of the applications that can be supported by MCC. Traditional m-learning applications have limitations in terms of high cost of devices and network, low network transmission rate, and limited educational resources [7–9]. Cloud-based mobile learning (m-learning) applications are introduced to solve these limitations. For example, utilizing a cloud with the large storage capacity and powerful processing ability, the applications provide learner with much richer services in terms of data (information) size, faster processing speed, and longer battery life. Most researchers state that, in order to avoid all attacks upon the e-learning environment, controlling access is paramount. One of the ways to do this is via authentication and authorization process. Jalal (2008) recommends an authentication process so as to identify a legal user process; this will overcome the illegal usage of application. A system which is too heavily secured will be difficult to be accessed by the user and it is more difficult when we use cloud computing for learning. In order to balance access and security, Saxena [15] mentions providing users with single sign on authentication and authorization services to all authorized web applications and web resources. Graf [17] suggests an approach to protecting intellectual property by extending the control of the copyright holder on the entire lifetime of the digital data. He suggests a method known as CIPRESS, which controls the access to the material. Yong [16] discusses another technical aspect concerning how to secure e-learning by digital identity design and privacy preservation. PremKumar. T and Prakash. V.R has proposed advanced UEP (Unequal Error

Protection) and selective encryption for video in wireless sensor networks. During block based encryption the error in bits occur due to extra dependency bits in the encrypted blocks [18]. This will cause packet loss during transmission and in media decoding misrepresentation will occur during video frame transmission. Seohyun Jeong, Eunji Lee, Sungju Lee, Youngwha Chung have proposed [21] slice-level selective encryption algorithm to achieve reduced computational workload compare to SECMPEG around 30 %. In SECMPEG whole I-frames are encrypted where I-frame size is larger when compared to B and P frames. In slice-level encryption, only first data in each slice is encrypted. The effect of encryption is attained in most of the I-frames and it develops an error propagation property in MPEG2 standard. In general MPEG video is done on duplication of group of pictures (GOPs). Each GOP is of I, P, B frames which are selected in sequence. I-frames are encoded as standard JPEG, where P or B frame are encoded for the difference between close frames based on motion compensation. When motion compensation cannot find matching block in close frames, the macro blocks associated with it are encoded as intra-coded mode and is called as I-block. This I-block contains the large amount of motion in P or B frames which are encoded as standard JPEGs. Encrypting the whole data is tedious. For providing proper level of security and to reduce the computational workload SECMPEG encrypts I-frame and I-block selectively. And it also provides 5 security levels. In those levels of security, level 3 encrypts I-frame whose size is larger than P- and B-frames. In addition 30 % data is needed for encryption in mobile phones without the reduction in security level. In slice level encryption of videos if the attacker after Compressing/encoding process distorts the first macro block in each slice that block is inconsistent with the header data. If the attacker tries to decode the distorted macro block with the correct header data, it propagates the error to the successive macro blocks in the slice. In this algorithm the attacker who does not have the key needs to decode/decompress the data which is transmitted to view the video.

Adnan M. Alattar, Ghassa I. Al-Regib and saud A. Al-Semari have proposed [20] to reduce the processing time by preserving the security. Three methods have been proposed with three different approaches: In Encrypting Intra-Coded Macro blocks alternatively, the data of nth I-macro block is encrypted and the rest I-macro blocks are not considered. This method is also called as Method I. Each and every I-macro block is encrypted by using the counter which keeps track of the macro blocks and it is updated in the beginning of each slice. Some of the blocks are left unencrypted and this is due to differential coding scheme. The processing time is less when compared to the encryption done on all I-macro blocks. In this the I-macro blocks are encrypted alternatively and the headers of all the predicted macro blocks are encrypted to improve the security level of the Method I, every header including the I-macro block are encrypted using DES algorithm. DES algorithm works on 64-bit segment and it starts from header of each predicted block.

The segment may include part of the header or of the entire header. If the segment which is encrypted includes the part of the header it causes the synchronization problem but it increases the security of the video transmission. In I-Macro blocks and the headers of predicted Macro blocks, the encryption is done on every I-macro block and every predicted nth macro block header. To perform this action two counters are used to keep track of the header of predicted macro block and encrypted I-macro block. DES algorithm is used for encrypting macro block and also the header. Dinoop and Durga [25] proposed dividing the video into dynamic size of files before it is uploaded into cloud storage so that it reduces uploaded time as well as downloading time. But it does not emphasis the secure way of uploading into the cloud storage.

Proposed Work

The steps involved in the proposed solution are given in the block diagrams 1 and 2. The video data are stored in different locations effectively through content Sharing and delivery network. In the proposed model for m-learning, video capturing is the first step. High definition quality cameras are used to capture the video and sound. Thus they create a virtual class room. The class room may be anywhere in the world, the users of m-learning only require the browser enabled hand held devices with the internet connection. The videos can be uploaded by only the register members of cloud. To ensure the security and access control for the m-learning video stored in the content delivery network (CDN) of cloud service provider, the time delay m-learning videos are divided into dynamic size of chunk files. In the second step we need to select each chunk files and attempt to select specific I frames of that chunk file to encrypt. The encrypted video streams are the combinations of I, P, and B frames. After selecting the I frame of a particular chunk files, the content of I frame in this file is arranged in matrix. Then we applied the light weighted encryption algorithm for a real time video streaming for the information stored in NxN matrix by choosing the position in that matrix randomly. Means apply our proposed selective encryption algorithm called masking based bit-xoring method before the video is going to be streamed lively to mobile devices or stored in cloud storage and stream by cloud server in offline mode.

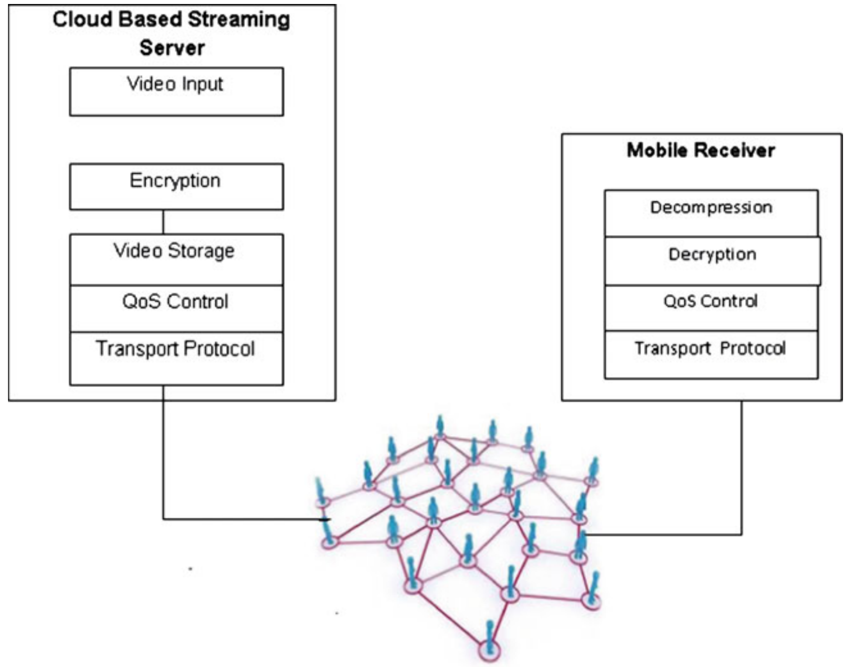


Fig. 1 8 × 8—masking

This step is repeated for all chunk files. Here we use MBBBXOR algorithm to Encrypt and Decrypt the video by considering an input of 128 bits size both data and key each time Selective encryption is a technique for encrypting only parts of a compressed video stream to reduce computational complexity (Bharagava and Shi, 1998; Deniz et al. 2007). It is not a new idea, as it has been proposed in several applications, especially, in multimedia systems (Lookabaugh et al. 2003). Selective encryption can be used to reduce the amount of power consumed by the encryption/decryption function for digital content. As only particular parts of the bit stream are encrypted, selective encryption can also enable new system functionalities such as allowing the previewing of content. Selective encryption algorithm has excellent features such as real-time transmission and error-propagation prevention. The server in the cloud environment along with the administrator (distributor) has the control and can manage the video stored in the "Storage as a Service" layer. It supports the streaming of all video file formats such as mp4, avi, wmv etc. The advantage of this cloud based model is, even if thousands of requests are placed on the server at a time, the server will be able to stream the video simultaneously to all the clients. The providers can upload the videos of any length and size in the form of block blobs to the cloud storage that can be accessed from anywhere at any time with providers permission. The providers andthe consumer's details are stored in the structured cloud table.

Proposed Encryption Algorithm

In general data owner stores their text as well as multimedia data in the cloud service provider (CSP). Since the multimedia data is passing through the third party (CSP) cloud service provider, and it must be done in a secure way. For these purposes however, data owner can apply standard cryptography algorithm such as AES, DES, IDEA, MD5, RC4 and 3DES for storing data and streaming multimedia data through the cloud service provider in a secure manner. In general, the data owner is concerned with the high security of the data but not the time taken for encrypting and decrypting end. Since cloud computing is used to stream both online in case of live video streaming and offline encrypted video and audio to multiple clients, the time required for decryption should be minimum. In our proposed system we implemented a cost effective cryptographic algorithm for streaming encrypted video to requested mobile users using cloud environment. The binary data for the chunk media file is split into 8×8 block segments and then, we are taking any square mask randomly from this 8×8 matrix based on the permutations. It is assumed that the intermediate compressed frame is split into 526 blocks, namely, S1, S2,. . .. . ., S526 as shown in Fig. 1. After applying MBBXOR method, we may get different values in the blocks. It is observed that MBBXOR method provides better security to an intermediate compressed data and therefore, the attacker cannot view or access the data. The general system architecture for cloud based m-learning system is

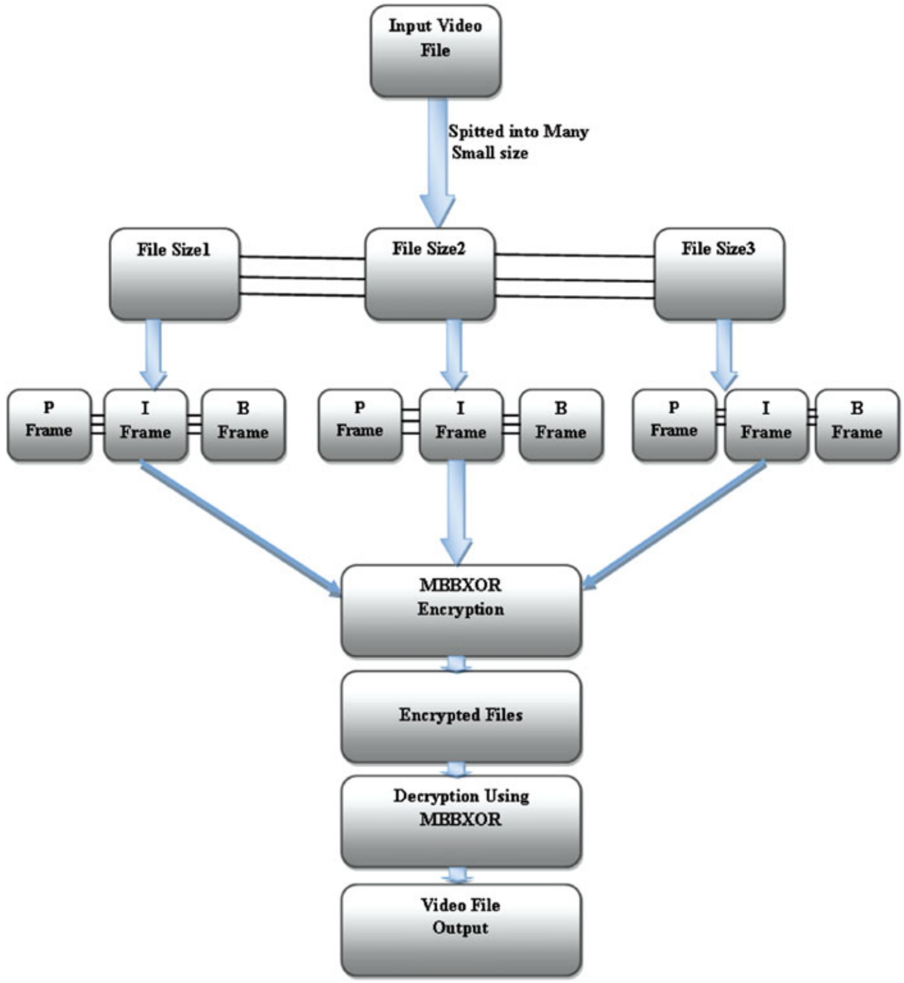


Fig. 2 General architecture for mobile based e-learning video streaming

given in Fig. 2 and the whole system architecture for our proposed cost effective encryption algorithm is given in Fig. 3.

For example in the above 8×8 matrix in Tables 1 and 2, we take four 3 × 3 mask and change the centre value by doing xoring all the nine values in each mask.

The algorithm steps involved in the proposed encryption and decryption algorithms are shown in section B.

Definition and Notations

Definition Encryption function. Let f (i, j) denote the elements of the plaintext in location (i, j). $f(i, j) = a_\ell$, for some $\ell = 1, \cdots n^2$. Denote $f(i, j) = 0$ if either $i < 1$ or $i > n$ or $j < 1$ or $j > n$. Let $E(I, J) = \{(i-1, j-1), (i, j+1), (i+1, j+1)\}$Define the encrypted value of $f'(i.j)$ of $f(i, j)$ are as follows.

$$f'(i,j) = \sum_{(l,k)\varepsilon \mathrm{E}(i,j)} \oplus f(i,j) \qquad (1)$$

Where RHS of equation represents the XORing of the $f(i, j)$ values in the 3×3 neighborhoods/mark centered at (i, j).

E.g.

$$P = \begin{bmatrix} 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 \end{bmatrix}_{f(2,2)=1} \qquad \begin{bmatrix} 1 & 0 & 0 & 1 \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 \end{bmatrix}_{f'(2,2)=0}$$

Definition Encryption processes. We modify the value f (i, j) as per the rule imposed by the permutation. For π_1, the value f (i, j) at position (i, j) corresponding to the P_1 is modified first, then the value $f(i, j)$ corresponding to P_2, then P_3 and so on. During the encryption process, the new value $f'(i, j)$ replaces the original value f (i, j) at (i, j). Formally,

S1	S2	…….	…….	
	S512	……..	…….	S526

Fig. 3 Architecture diagram for proposed system

Table 1 8 × 8—binary order

1	0	0	1	1	1	1	0
0	0	1	1	1	0	1	1
0	1	0	1	0	1	0	1
1	1	0	1	0	1	0	1
1	0	1	0	0	1	1	0
0	1	0	1	0	1	1	1
1	0	1	1	1	0	0	1

1 2

Table 2 8 × 8 binary order value changed

1	0	0	1	1	1	1	0
0	1	1	1	1	0	1	1
0	1	0	1	0	1	0	1
1	1	0	1	1	0	0	1
1	0	1	0	0	1	1	0
0	1	0	1	0	1	0	0
1	0	1	1	1	0	0	1

1 2

Unchanged

$$E_{\pi 1}(f(i,j)) = \sum \oplus \widetilde{f}(l,k) \tag{2}$$

Where $\widetilde{f}(l.k) = \{f(l,k)$, if the position $(l,\ k)$ is not yet visited as per the order given by π_1.

$\{f^{'}(l,\ k)$, if the position $(l,\ k)$ is already visited during the encryption process.

Definition

We define, $E_{\pi_1}(P) = \{E_{\pi_1}(f(i,j))/i,j = 1,2,\cdots,n\}$. Similarly we define E_{π_2}. We call E_{π_1}, the encryption process generated by π_i, i = 1, 2.

Encryption Algorithm

Step1: Initially the input video is spitted into different size of chunk files.

Step2: Next select each chunk files and read the I frame of each chunk file as a binary data and arrange them into a square matrix of size (n × n) with $\{a_1, a2\ldots a_n{}^2\}$.

$$\text{Let P} = \begin{bmatrix} a_1 & a_2 & \ldots & a_{n^2} \\ a_{n+1} & a_{n+2} & \ldots & a_{n^n} \\ . & . & . & . \\ a_{n^2-n+1} & a_{n^2-n+2} & \ldots & a_{n^2} \end{bmatrix}$$

Comparatively, encryption applied on that binary format of the video files takes less time and provides adequate security.

Step 3: Arrange the binary data of the I frame in each video/audio chunk files into a square matrix of size (n x n) with the 1st n elements occupying the 1st row, 2nd n elements occupying the 2nd row and so on. The value at position (i, j) is as follows. Let a(i,j) be the original value at(i,j), i, j = 1, 2,…,n. Let Z = a(i-1, j-1) ⊕ a(i-1, j) ⊕ a(i-1, j + 1) ⊕ (a(i, j-1) ⊕ a(i, j) ⊕ a(i, j + 1) ⊕ a(i + 1, j-1) ⊕ a(i + 1,j) ⊕ a(i + 1,j + 1). New value b (i, j) = Z.

Step 4: Take keys K = $\{K_1, K_2\ldots k_n{}^2\}$ and L = $\{L_1, L_2\ldots L_n{}^2\}$ of size n^2.

Step 5: Take selective random permutations for position in the square matrix in each I frame of each chunk files $\pi_{1=}\{P_1, P_2\ldots P_n\}$ and $\pi_{2=}\{Q_1, Q_2\ldots, Q_n\}$ of the integers {1, 2, 3… n}.

Step 6: Perform P ⊕ K in the square matrix and do the following steps. P ⊕ K, where P = $\{P_1, P2\ldots P_n\}$ and K = $\{K_1, K2\ldots K_n\}$.

Step 7: Then choose the location (i, j) randomly through the random permutation of $\pi_{1=}\{P_1, P_2\ldots P_n\}$. I.e. we choose the position in the matrix (P ⊕ K) at random and selective position using random permutation π_1 and cover some of the position in the matrix. The new b (i, j) is taken as the binary value at (i, j) position for further processing. Old value is erased.

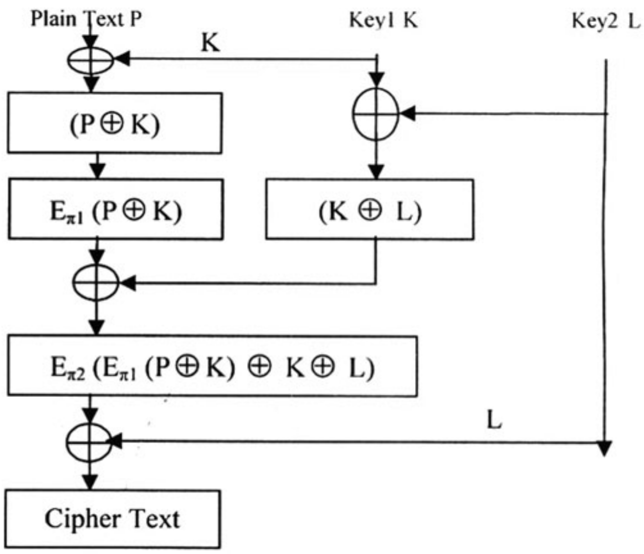
Step 8: Get the cipher text b (i, j), i = 1, 2,…n and j = 1, 2,…n and arrange the cipher text in the square matrix P.

Step 9: Similar to step6 perform P ⊕ L, where L = $\{L_1, L_2, L_n{}^2\}$.

Step 10: Repeat steps from 7 to 8 with the random permutation of $\pi_2 = \{q_1, q_2, q_n\}$.

Step 11: Repeat steps from 1 to 10 for each chunk file.

The block diagram for encryption algorithm is given below.



Experimental Evaluation and Security Analysis

To analyze the performance of the proposed selective encryption algorithm, we consider the execution time. We have used eucalyptus private Cloud Environment on HCL INTEL COREDU 385G Six Cor AMD Processor with 32 GB of RAM and 500 GB HD in our experiment. For video transmission, we used UDP transmission protocol to send and receive the video packets through the network channel. Java programming language has been used since it has many advantages with the network programming. Table 3 shows that the proposed algorithm, MBBXOR, is optimized and giving better performance in terms of encryption/decryption time as compared with RC4 and MD5. The time efficiency of MBBXOR algorithm takes less time as compared with existing MD5 and RC4 and is shown in Figs. 4 and 5.

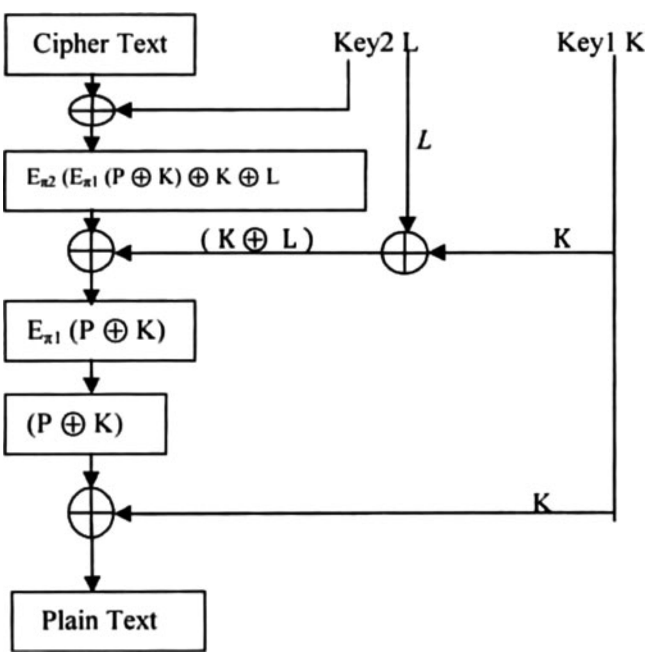
Decryption Algorithm

Step 1: Modify the value at b (i, j) in the matrix as follows. Let W = b(i-1.j-1) ⊕ b(i-1,j) ⊕ b(i-1,j + 1) ⊕ b(i,j-1) ⊕ b (i,j) ⊕ b(i,j + 1) ⊕ b(i + 1,j-1) ⊕ b(i + 1,j) ⊕ b(i + 1, j + 1). If we define the value a $(i, j) = W$

Step 2: Modify the value b (i, j) at position (i, j) as per the reverse permutation order of π_2 and π_1 respectively. i.e., Q_n, Q_{n-1}. . .Q_2, Q_1 and P_n, P_{n-1}. . .P_2, P_1. (Reverse order of the order used in encryption).

Step 3: The output a (i, j), i = 1, 2. . . n, j = 1, 2. . . n is the original plain text. For any (i, j), if a (i, j) is outside the given matrix, we take a (i, j) = 0 and similarly for b(i, j) during both encryption and decryption.

The block diagram for decryption algorithm is given below.



Conclusion

The proposed algorithm for video encryption and decryption during streaming in cloud computing takes less time as compared with RC4 and MD5 with required level of security

Table 3 Encryption and decryption time

	Encryption time (in MS)			Decryption time (in MS)		
File size (in MB)	RC4	MD5	MBBXOR	RC4	MD5	MBBXOR
10	200	210	193	198	210	187
15	257	263	242	257	265	242
20	389	418	360	387	420	358
25	394	418	378	390	419	372
30	433	480	420	427	476	415

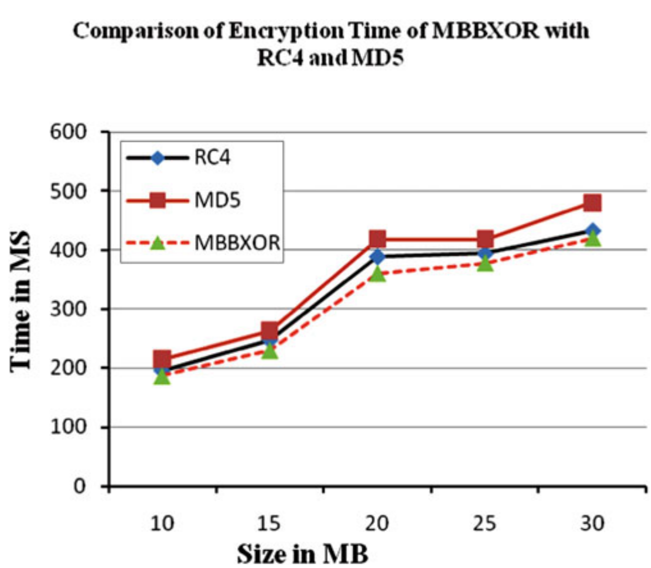


Fig. 4 Comparison of MBBXOR encryption time with RC4 and MD5

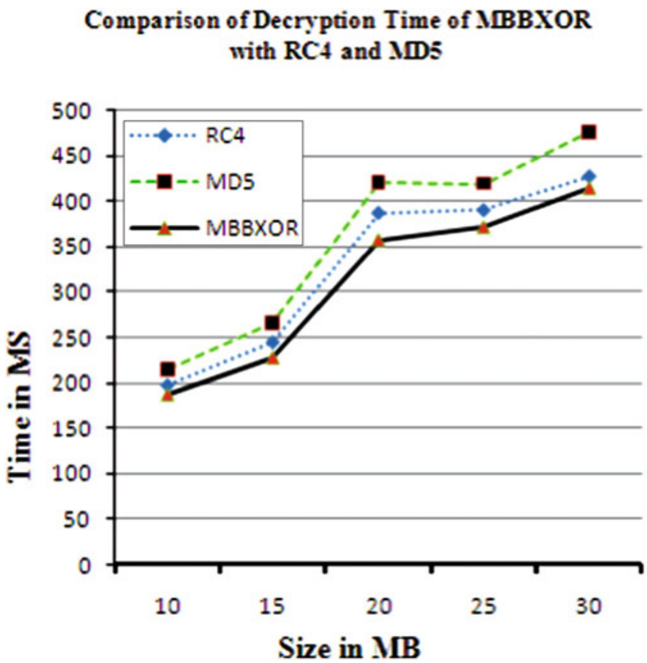


Fig. 5 Comparison of MBBXOR decryption time with RC4 and MD5

because we encrypted only selected position in the I frame of all chunk files. In future we try to fine tune this algorithm for secure storing and streaming of e-learning video to mobile devices by considering other parameter such as bandwidth and power consumption for streaming encrypted multimedia to mobile devices.

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A Multi-Level Privacy Scheme for Securing Data in a Cloud Environment

Ezekiel K. Olatunji, Matthew O. Adigun, and Paul Tarwireyi

Abstract

Privacy concern is often cited as one of the key factors that impede large-scale adoption of the cloud computing paradigm by enterprise customers. Existing solutions to privacy issue with respect to cloud computing, commonly through encryption mechanisms, often result in performance problem. This paper proposes and presents a multi-level privacy support scheme for addressing the trade-off between privacy of user's data stored in the cloud and system performance. This is achieved by using encryption algorithms with varying strengths to protect the privacy of different categories of user's data depending on their privacy sensitivity. Simulation results, using Jindael AES encryption algorithm as case study, lends credence to the efficacy of the proposed privacy scheme.

Keywords

Cloud computing • Data privacy • Encryption algorithm • System performance

Introduction

Cloud computing is a growing and promising computing paradigm in which scalable, dynamic computing resources and services are provisioned on demand and on a pay-per-use model. The three key models by which cloud computing delivers its services to the end user are software as a service (SaaS), platform as a service (PaaS) and infrastructure as a service (IaaS). These delivery models exhibit certain characteristics like on-demand self-service, multi-tenancy, ubiquitous network, measured service, rapid elasticity, and so on [1].

SaaS is a model of software delivery whereby a provider licences an application to customers for use as a service on demand. Salesforce and Goggle Apples (mail, docs) are some examples of SaaS model [2]. PaaS is a delivery of computing platform and solution stack as a service. It facilitates the deployment of application without the cost and complexity of buying and managing the underlying hardware and software layer. It provides the facilities required to support the complete life cycle of building and delivering web application and service. An example is Goggle App Engine. IaaS refers to a system that provides its users with computing resources delivered as a service, including servers, network equipment, memory, CPU, and disk space [3]. IaaS platform uses a pay-as-you-go pricing model. An example is Amazon.web.

Many benefits are afforded by cloud computing and these include, but not limited to, fast deployment, pay-per-use, rapid provisioning, rapid elasticity, lower costs, scalability, ubiquitous network access, greater resiliency, hypervisor protection against network attacks, rapid re-composition of service, low cost disaster recovery and data storage solution, on-demand security controls, and real-time detection of system tampering [1]. According to [4], providing on-demand access to a shared pool of computing resources in a self-serviced, dynamically scaled and metered manner, cloud computing offers compelling advantages in cost, speed and efficiency.

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_83,

However, despite the hype, popularity and numerous benefits of cloud computing technology security and privacy concerns often top the list of challenges that currently inhibit its large-scale adoption by enterprise customers [1]. The multi-tenancy nature of most cloud computing models in which resources are shared among users may lead to breach of data privacy. Furthermore, the exact location in the cloud in which users' data are stored not being under the control of nor known to the user has been a cause for concern with respect to privacy issue. These reasons necessitate the need to provide an effective mechanism for protecting the privacy of users' data in the cloud. This work is another effort in addressing the security and privacy challenges of cloud computing technology, particularly the privacy issue.

Data privacy has to do with appropriate restriction placed by an individual on the disclosure of his/her private information [5]. The need to maintain information privacy is applicable to collected personal information such as medical records, financial data, business-related information, criminal records, and so on. Privacy concern exists whenever personally identifiable information (PII) is collected and stored by another party in one form or the other [6]. A cloud cannot be used for storing and processing if it is not secure. The major problem regarding privacy in the cloud, according to [7], is how to secure PII from being used by unauthorized users, how to prevent attacks against privacy (such as Identity theft) and how to maintain control over disclosure of private information.

Encryption of data is one of the common ways of protecting data in the cloud. However, utilizing encryption technique with a complex algorithm usually has adverse effect on system performance, since such algorithm consumes a lot of resources, particularly the CPU [2]. This paper addresses the privacy issue in a cloud computing environment by describing a technique for providing an efficient and effective privacy protection scheme that aims to strike a good balance between privacy protection and system performance within the cloud environment. The need to address the trade-off between security and system performance is very crucial because a secure system that is unbearably too slow will not hold much attraction to the intended customers. The scheme being proposed is achieved by varying the complexity of the encryption algorithm being employed according to the sensitivity of user's data that are to be stored in the cloud.

The remainder of this paper is structured as follows: Section "Related Works" provides a brief review of related work, while the requirements needed for the privacy scheme are high-lighted in section "Requirements for the Proposed Privacy Scheme". A detailed description of the approaches employed for enforcing privacy of user's data as well as achieving satisfactory system performance is given in section "Privacy Enforcement Approach". A sample usage scenario of the privacy scheme is given in section "Usage Scenario". For a proof of concept of the scheme being described, the result of a simulation experiment carried out is discussed in section "Result of Simulation Experiment". Section "Conclusion and Future Work" concludes the paper and gives direction for future work.

Related Works

A comprehensive outline on various researches and trends in cloud computing was presented in [8]. Reference [9] reported on the risks inherent in adopting cloud computing with respect to legal compliance and data privacy. The research work being reported in this paper is another effort aimed at mitigating one of the risks that inhibit wide-scale adoption of the cloud computing. The need to develop a good digital infrastructure that will allow for effective handling of security and privacy concerns in the cloud was strongly emphasized by [10]. The authors of [11] provided an overview of security and privacy challenges pertinent to public cloud computing. They also pointed out some considerations organizations should take when outsourcing data, applications and infrastructure to a public cloud environment. A comprehensive set of guidelines on designing privacy-aware cloud services was provided by [12]. Some of these guidelines are taken into consideration in our study.

A privacy-aware data storage and processing architecture for cloud computing environment was presented by [13]. In their work, a set of security protocols for ensuring legal compliance with respect to privacy requirements of a consumer data were specified. The work of [14] is similar to that of [13]. It also outlined a set of security protocols for securing data in the cloud. Both [13] and [14] took advantage of the tamper-proof capability of secure co-processors. However, the impact of their approach on system performance was not their focus nor major consideration. Concern for trade-off between security and system performance is the focus of the study being reported in this paper. This study provides an approach that enhances system performance while assuring the privacy of user data. The work in [15] presented an architecture to protect the data confidentiality of guest machines in the cloud. The author made use of virtualization technology and trusted computing technology to construct a secure and robust virtualization platform. The approach adopted as claimed by the author would make it impossible for the cloud computing service provider to access private data of their client.

An approach for data privacy in hybrid cloud was presented by [16]. In their work, customer's data were divided into two categories: sensitive and insensitive. The sensitive data were kept within the custody of the organization's own private network, while the insensitive were allowed to be stored into the public cloud. Access to private data from the public cloud is subjected to authentication verification. The authentication procedure would refuse request to private data from sources outside of the organization. The approach presented in their work could prevent unauthorized access to the sensitive data via authenticating all requests to sensitive data. However, privacy protection is not clearly demonstrated in their work, since the sensitive data needing privacy preservation were kept within the custody of the owner. Prescribing a mechanism for granting authorized access to sensitive data being stored in the public/hybrid cloud while still preserving their privacy would be most desirable. Our study prescribes mechanisms for protecting data stored in the public cloud as well as mechanism for granting access to such data in a way as not to unduly impair system performance.

A privacy protection scheme for the cloud computing was proposed by the authors in [2]. Their work was embarked upon in order to reduce the overhead usually involved in privacy protection stored in the cloud when encryption is employed. They claimed that their simulation results of the scheme outperformed other security schemes that they considered. In a similar vein, the work of [17] made an effort to address the trade-off between performance and security of cryptographic algorithms used for protecting users' data in the cloud. They provided guidelines on what they considered as best security options for cloud customers. While our work is similar to those of [2] and [17], our approach is different from theirs. Their approach is more cloud provider-centric, whereas ours is more user-centric. In [2] and [17], it is the provider that classifies user's data into privacy categories, whereas, in our approach it is the user that classifies his/her data into privacy categories according to his/her perceived degree of privacy sensitivity of the data. Furthermore, the user must necessarily approve of the encryption algorithm to be employed.

An algorithm to implement data hiding in the cloud by using biological characteristics of DNA sequences was proposed by [18]. This was in order to solve the common problem of data confidentiality that exists in a typical cloud environment. In this work, before storing user data in the cloud, the data will go through three transformation processes. It is the final form of the data that is sent to the cloud. The authors were able to show that the possibility of an attacker guessing the correct data is near zero, actually $1/(163 \times 10^6) \times (1/24) \times (1/24)$. The original data, if required, can be retrieved by going through the transformation's processes in the reverse order of which it was originally carried out. Their goal of hiding information in the cloud from an intruder was achieved. Thus data can be safely stored in any cloud using this technique. However, before data can be processed in the cloud, the provider would have to be absolutely trustworthy. The DNA reference sequence to be chosen from an appropriate database (such as EBI) is like a secret key that can only be shared with a trusted provider. Furthermore, like most other encryption algorithms, this technique may adversely impact on system performance.

Requirements for the Proposed Privacy Scheme

In this section, we high-light the requirements that underpin the privacy scheme being described in this paper.

Environment for the Proposed Privacy Scheme

In this work, a typical cloud environment in which the provider manages both the infrastructure and software and a consumer or user uses the software and storage provided is assumed. Both the provider and consumer, as usual, communicate via the Internet.

Protocols

A set of protocol steps for transferring user data to the cloud for storage and for processing of user data will need to be specified. A user will be required to comply with specified protocols before transferring his/her data to the cloud provider for storage in the cloud. Similarly, the cloud service provider would need to comply with some specified protocols in processing user's data.

Encryption Techniques

Encryption techniques are required to provide the needed protection over an SSL session as well as enforcement of user's requirement for privacy. Both the user and the provider might need to mutually agree on the type of encryption algorithm to be employed. These encryption algorithms would, in particular, need to be of varying strength. The strength of an encryption algorithm can objectively be measured by its cracking year [2]. The requirement for encryption algorithms with varying strength is one of the strategies for providing multi-level privacy support for user's data in the cloud as well as for striking a good balance between effective privacy protection and satisfactory system performance.

Privacy Enforcement Approach

This section provides a detail description of the approaches employed by the privacy scheme being described in this paper.

Encryption Algorithm Categorization

The multi-level privacy scheme being proposed makes use of an encryption algorithm which has varying strengths to protect the privacy of different categories of users' data. The strength of an algorithm can be said to be directly proportional to its CPU utilization and this inversely impacts overall system performance. This strength can be measured by its cracking year [2]. In order to provide support for multi-level privacy needs, the encryption algorithms to be used will be categorized into three: weak (not too strong), strong and very strong, based on their strength. However, even the 'weak' encryption algorithm must still be adequate in providing the needed protection. Usually, encryption algorithms with longer key sizes are stronger and more secure than those with shorter key sizes. An encryption with key length 80 bits is said to be adequate, even though encryption algorithm with key length 128 bits is often used [19]. Using Jindael AES encryption algorithm [20] as an example, the algorithm can be categorized as follows:

- Weak Encryption: AES with key length 128 bits
- Strong Encryption: AES with key length 192 bits
- Very strong Encryption: AES with key length 256 bits

Regular DES [21] which uses 56 bits key has been considered insufficient for many applications (such as military). However, for purpose of illustration, the regular DES and variants of Triple DES (TDES) can be classified as follows:

- Weak Algorithm: Regular DES
- Strong Algorithm: TDES with $k1 = k3 \neq k2$
- Very strong Algorithm: TDES with $k1 \neq k2 \neq k3$

Where k1, k2 and k3 are DES keys, each of 56 bits long excluding parity bits

In TDES [21], a plaintext is first encrypted with key k1, the result is then decrypted with key k2 and the result of this is further encrypted with key k3. The decryption of TDES protected data is carried out in the reverse order.

Data Categorization and Privacy Specification

Rather than encrypting the entire user's data with a reliable strong encryption algorithm, user's data are first grouped into categories based on their privacy sensitivity and then each category is protected with an encryption algorithm of commensurate strength. A user will be expected to divide his/her data into three privacy categories depending on his/her perceived degree of sensitivity of the data. The categories are low, medium and high privacies. Each category of data will be protected with an encryption algorithm of commensurate strength.

Low Privacy Data

Data in this category is assumed not to be very sensitive and therefore a relatively weak but adequate encryption algorithm will be used to protect this category of data. For example, an AES algorithm of key length 128 may be sufficient to encrypt this category of data.

Medium Privacy Data

Data in this category is fairly sensitive and the user will want a fairly strong encryption algorithm for its protection. For example, an AES algorithm of key length 192 bits can be used to protect this category of data.

High Privacy Data

Data in the high privacy category is very sensitive and the owner will want a very strong encryption algorithm to protect it. This category, for example, can be protected with AES algorithm of key length 256 bits.

Efficient Provision of Privacy for User's Data

This sub section describes the approach of providing efficient and effective privacy for user's data in the cloud. In order to ensure optimal privacy of user's data in the cloud and to ensure satisfactory system performance, the user data is grouped into three privacy categories: low, medium and high (as explained in sub section B above), while the encryption algorithm is also categorized into three: weak, strong, and very strong (as explained in sub section A above). Data in the low privacy category will be protected with a relatively weak but sufficient encryption algorithm (for example, AES algorithm using key length 128 bits). Data in the medium privacy category will be encrypted with an encryption algorithm in the strong encryption category (for example, AES using key length 192 bits), while data in the high privacy category will be protected with a very strong encryption algorithm category (such as AES using key length 256 bits).

No particular encryption algorithm is being advocated. The emphasis in this paper is on using encryption algorithm with varying strength to protect the privacy of users' data according to the privacy sensitivity of the data. That is, the low, medium and high privacy data categories to respectively be encrypted with relatively weak, strong and very strong encryption algorithms. A combination of different encryption algorithms can also be employed. For example, the work of [21] has shown that, in terms of performance, Blowfish algorithm is faster than both TDES and AES. Thus it is possible to use a mix of the TDES, AES and Blowfish (preferably Twofish [22]) encryption algorithms.

Protocol for Data for Storage and Processing

This sub section describes the set of protocols to be followed by a user before transferring data to the cloud provider for storage and to be followed by the service provider for storing and processing data.

1. The user categorizes the data according to their privacy classes.
2. He/She sends each category of data encrypted to the provide in order to secure it over SSL session.
3. Before storing the data in the cloud, the service provider protects each category of data with an encryption algorithm that is having the strength that is commensurate with its privacy category as described in subsection A and B above.
4. The data will be decrypted before being processed in the server and the result also will be encrypted with corresponding encryption algorithm category before being sent to the user.

Usage Scenario

In an e-health scenario, for example, patients' health records may have to be kept online to make them accessible to hospital personnel such as Physicians, Nurses and Health Record Officers. In order to take advantage of the multi-level privacy support provided by our privacy scheme, whose aim is to strike a balance between security of user's data and system performance, patients' data might need to be classified into the privacy categories shown below. Each category will then be protected with its corresponding encryption algorithm category.

- High Privacy: Patient's medical record (for example ID Number, Nature of sickness and so on)
- Medium Privacy: Patient's Bio-data (such as Name, Age, and Next of Kin)
- Low Privacy: Information about the Physician (for example, Name, and specialization), Caregivers and Hospital in charge of the patient

Result of Simulation Experiment

In order to prove the efficacy of the privacy scheme being described in this paper, a simulation experiment, using AES algorithm, was carried out. The AES encryption algorithm was written in Java programming language and run on AMD Athlon™ X 2 Dual core Q-66 system. The system has a processor speed of 2.20 GHz; RAM size of 3.00 G bytes, and runs on Windows 7 Professional. The algorithm was used to encrypt sample data and then tested using key length sizes: 128 bits, 192 bits and 256 bits. The same test data was used for each of the key sizes. It was assumed that the test data belongs to the low, medium and high privacy data category when using key sizes 128 bits, 192 bits and 256 bits respectively. For each key size and each run, the execution time was measured. Due to the sizes of data used for testing and simulation, the execution time was measured in nanoseconds. The algorithm was run for two sets of data for each key size. Table 1 is the result obtained for one of the data set. The resulting relative execution time is depicted in Fig. 1.

In order to obtain a fairly accurate run time, each run was carried out 1,000 times, being put within a loop. It is the average of these run times that was recorded in Table 1 for the three key sizes. From Fig. 1, as expected, the AES

Table 1 AES algorithm run times (in nanoseconds) using varying key sizes to encrypt data

Run sequence	256 bits	192 bits	128 bits
1.	91,827	93,294	84,779
2.	90,008	101,554	86,481
3.	109,511	86,262	87,521
4.	110,327	97,680	86,152
5.	103,647	109,486	99,826
6.	116,192	87,275	86,617
7.	117,728	85,451	96,583
8.	109,303	98,732	86,668
9.	101,926	102,780	103,681
10.	86,746	116,239	87,447
Average	103,721.5	97,875.3	90,575.5

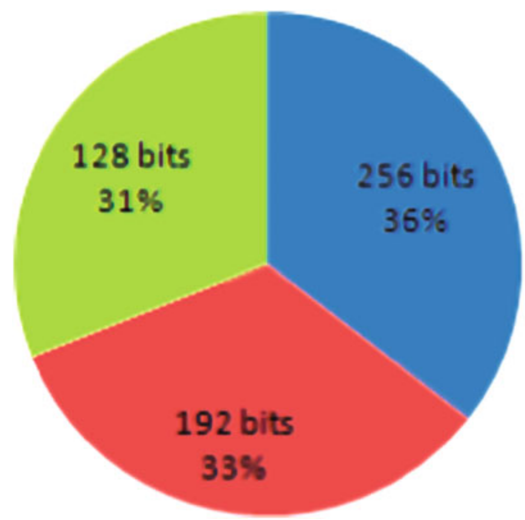

Fig. 1 AES algorithm run times using varying key sizes to encrypt data

encryption algorithm using key length of 256 bits consumed more processor time than when key length 192 bits was used, and AES with key length of 192 bits also consumed more processor than that of key length 128 bits.

Simulation results further show that the disparity in run times of the three key sizes as shown in Fig. 1 will increase with increase in the quantity of data. That is, the more the volume of data the more CPU time will be required by AES algorithm with key length of 256 bits compared to using key length of 192 bits; likewise, key length of 192 bits will consume more CPU time relative to using key length of 128 bits with increase in the volume of data.

From the simulation results and what is explained in the preceding paragraph, it is evident that a privacy scheme that provides multi-level privacy support will be able to greatly enhance system performance while assuring effective privacy protection for user's data in the cloud, especially with a huge dataset. Thus the scheme provides a good balance between system performance and privacy protection of data stored in the cloud environment.

Conclusion and Future Work

A multi-level privacy supporting scheme for securing data in a cloud environment has been presented in this paper. The goal of the scheme is to provide a good balance between system performance and privacy protection of data in the cloud. This can be and has been achieved by making use of an encryption algorithm with varying strengths and by making a user to classify his/her data in to three different privacy categories depending on their relative privacy sensitivities. The complexity of an encryption algorithm for protecting each category of data is made to vary in proportion to the relative privacy sensitivity of the data. That is, relatively weak encryption algorithm to be used for data in low privacy category and a stronger algorithm is used for data with higher privacy sensitivity. The next stage in this work is to experiment on the effects on system performance if more than three levels of privacy category are supported and when only two privacy levels are supported. This is to enable us find out the number of privacy categories that will provide optimal balance between effective privacy protection and system performance.

Acknowlegement This work is based on the research supported in part by the National Research Foundation of South Africa—Grant UID: TP11062500001 (2012–2014). The authors also acknowledge funds received from industry partners: Telkom SA Ltd, Huawei Technologies SA (Pty) Ltd and Dynatech Information Systems, South Africa in support of this research.

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