LNCS 8017

Sakae Yamamoto (Ed.)

Human Interface and the Management of Information

Information and Interaction for Health, Safety, Mobility and Complex Environments

15th International Conference, HCI International 2013
Las Vegas, NV, USA, July 2013
Proceedings, Part II

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HCI2013
INTERNATIONAL

Springer

Lecture Notes in Computer Science 8017

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Volume Editor

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ISSN 0302-9743 e-ISSN 1611-3349
ISBN 978-3-642-39214-6 e-ISBN 978-3-642-39215-3
DOI 10.1007/978-3-642-39215-3
Springer Heidelberg Dordrecht London New York

Library of Congress Control Number: 2013941251

CR Subject Classification (1998): H.5, H.4, H.3, J.2, J.3, J.7

LNCS Sublibrary: SL 3 – Information Systems and Application,
incl. Internet/Web and HCI

Typesetting: Camera-ready by author, data conversion by Scientific Publishing Services, Chennai, India

Printed on acid-free paper

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

Foreword

The 15th International Conference on Human–Computer Interaction, HCI International 2013, was held in Las Vegas, Nevada, USA, 21–26 July 2013, incorporating 12 conferences / thematic areas:

Thematic areas:

- Human–Computer Interaction
- Human Interface and the Management of Information

Affiliated conferences:

- 10th International Conference on Engineering Psychology and Cognitive Ergonomics
- 7th International Conference on Universal Access in Human–Computer Interaction
- 5th International Conference on Virtual, Augmented and Mixed Reality
- 5th International Conference on Cross-Cultural Design
- 5th International Conference on Online Communities and Social Computing
- 7th International Conference on Augmented Cognition
- 4th International Conference on Digital Human Modeling and Applications in Health, Safety, Ergonomics and Risk Management
- 2nd International Conference on Design, User Experience and Usability
- 1st International Conference on Distributed, Ambient and Pervasive Interactions
- 1st International Conference on Human Aspects of Information Security, Privacy and Trust

A total of 5210 individuals from academia, research institutes, industry and governmental agencies from 70 countries submitted contributions, and 1666 papers and 303 posters were included in the program. These papers address the latest research and development efforts and highlight the human aspects of design and use of computing systems. The papers accepted for presentation thoroughly cover the entire field of Human–Computer Interaction, addressing major advances in knowledge and effective use of computers in a variety of application areas.

This volume, edited by Sakae Yamamoto, contains papers focusing on the thematic area of Human Interface and the Management of Information, and addressing the following major topics:

- Complex Information Environments
- Health and Quality of Life
- Mobile Interaction
- Safety in Transport, Aviation and Industry

The remaining volumes of the HCI International 2013 proceedings are:

- Volume 1, LNCS 8004, Human–Computer Interaction: Human-Centred Design Approaches, Methods, Tools and Environments (Part I), edited by Masaaki Kurosu
- Volume 2, LNCS 8005, Human–Computer Interaction: Applications and Services (Part II), edited by Masaaki Kurosu
- Volume 3, LNCS 8006, Human–Computer Interaction: Users and Contexts of Use (Part III), edited by Masaaki Kurosu
- Volume 4, LNCS 8007, Human–Computer Interaction: Interaction Modalities and Techniques (Part IV), edited by Masaaki Kurosu
- Volume 5, LNCS 8008, Human–Computer Interaction: Towards Intelligent and Implicit Interaction (Part V), edited by Masaaki Kurosu
- Volume 6, LNCS 8009, Universal Access in Human–Computer Interaction: Design Methods, Tools and Interaction Techniques for eInclusion (Part I), edited by Constantine Stephanidis and Margherita Antona
- Volume 7, LNCS 8010, Universal Access in Human–Computer Interaction: User and Context Diversity (Part II), edited by Constantine Stephanidis and Margherita Antona
- Volume 8, LNCS 8011, Universal Access in Human–Computer Interaction: Applications and Services for Quality of Life (Part III), edited by Constantine Stephanidis and Margherita Antona
- Volume 9, LNCS 8012, Design, User Experience, and Usability: Design Philosophy, Methods and Tools (Part I), edited by Aaron Marcus
- Volume 10, LNCS 8013, Design, User Experience, and Usability: Health, Learning, Playing, Cultural, and Cross-Cultural User Experience (Part II), edited by Aaron Marcus
- Volume 11, LNCS 8014, Design, User Experience, and Usability: User Experience in Novel Technological Environments (Part III), edited by Aaron Marcus
- Volume 12, LNCS 8015, Design, User Experience, and Usability: Web, Mobile and Product Design (Part IV), edited by Aaron Marcus
- Volume 13, LNCS 8016, Human Interface and the Management of Information: Information and Interaction Design (Part I), edited by Sakae Yamamoto
- Volume 15, LNCS 8018, Human Interface and the Management of Information: Information and Interaction for Learning, Culture, Collaboration and Business (Part III), edited by Sakae Yamamoto
- Volume 16, LNAI 8019, Engineering Psychology and Cognitive Ergonomics: Understanding Human Cognition (Part I), edited by Don Harris
- Volume 17, LNAI 8020, Engineering Psychology and Cognitive Ergonomics: Applications and Services (Part II), edited by Don Harris
- Volume 18, LNCS 8021, Virtual, Augmented and Mixed Reality: Designing and Developing Augmented and Virtual Environments (Part I), edited by Randall Shumaker
- Volume 19, LNCS 8022, Virtual, Augmented and Mixed Reality: Systems and Applications (Part II), edited by Randall Shumaker

- Volume 20, LNCS 8023, Cross-Cultural Design: Methods, Practice and Case Studies (Part I), edited by P.L. Patrick Rau
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- Volume 24, LNAI 8027, Foundations of Augmented Cognition, edited by Dylan D. Schmorrow and Cali M. Fidopiastis
- Volume 25, LNCS 8028, Distributed, Ambient and Pervasive Interactions, edited by Norbert Streitz and Constantine Stephanidis
- Volume 26, LNCS 8029, Online Communities and Social Computing, edited by A. Ant Ozok and Panayiotis Zaphiris
- Volume 27, LNCS 8030, Human Aspects of Information Security, Privacy and Trust, edited by Louis Marinos and Ioannis Askoxylakis
- Volume 28, CCIS 373, HCI International 2013 Posters Proceedings (Part I), edited by Constantine Stephanidis
- Volume 29, CCIS 374, HCI International 2013 Posters Proceedings (Part II), edited by Constantine Stephanidis

I would like to thank the Program Chairs and the members of the Program Boards of all affiliated conferences and thematic areas, listed below, for their contribution to the highest scientific quality and the overall success of the HCI International 2013 conference.

This conference could not have been possible without the continuous support and advice of the Founding Chair and Conference Scientific Advisor, Prof. Gavriel Salvendy, as well as the dedicated work and outstanding efforts of the Communications Chair and Editor of HCI International News, Abbas Moallem.

I would also like to thank for their contribution towards the smooth organization of the HCI International 2013 Conference the members of the Human–Computer Interaction Laboratory of ICS-FORTH, and in particular George Paparoulis, Maria Pitsoulaki, Stavroula Ntoa, Maria Bouhli and George Kapnas.

May 2013 Constantine Stephanidis
General Chair, HCI International 2013

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HCI International 2014

The 16th International Conference on Human–Computer Interaction, HCI International 2014, will be held jointly with the affiliated conferences in the summer of 2014. It will cover a broad spectrum of themes related to Human–Computer Interaction, including theoretical issues, methods, tools, processes and case studies in HCI design, as well as novel interaction techniques, interfaces and applications. The proceedings will be published by Springer. More information about the topics, as well as the venue and dates of the conference, will be announced through the HCI International Conference series website: http://www.hci-international.org/

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Part I
Complex Information Environments

Power and Energy Management: A User-Centered System-of-Systems Engineering Approach

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Abstract. Energy is considered a resource for survival. The demand and supply of natural resources used to generate, transmit, and consume the power make the puzzle for the human race even more complex. Other physical elements like water, copper wiring, electric cars, nuclear power plants, oil platforms, consumer tablets, and buildings to name a few are attached to the energy ecosystem adding mass confusion to a system failing to keep up with the global changes. This paper deals with a methodology for designing a smarter power and energy management system, following the V-cycle. It focuses on building a model using systems modeling language (SysML). The application of systems engineering process in power and energy is presented in this paper as well as the devices in the systems which are going to have a software component enveloping the digitization and proliferation of better, faster, and more effective ways of reusing our best practices in systems engineering. This paper introduces a system-of-systems engineering approach codified in client power management software needed for the urgent transformation of global power systems.

Keywords: Systems engineering, energy, power management.

1 Introduction

By creating sustainable cities, the planet could become smarter. As a matter of fact, an urbanizing world means that cities are “gaining greater control over their development, economically and politically. Cities spread wider and wider but at the same time they are becoming overcrowded and polluted while energy consumption increases exponentially. Cities are also being empowered technologically, as the core systems on which they are based become instrumented and interconnected, enabling new levels of intelligence. In parallel, cities face a range of challenges and threats to their energy sustainability across all their core systems that they need to address

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S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 3–12, 2013.

holistically. To seize opportunities and build sustainable prosperity, cities need to become efficient in utilizing power and energy resources. The evolution of technology and communication can allow the inhabitants to live a better and easier life. Nowadays, high-technology can be employed by the users daily. An effective energy management initiative is going to answer this tradeoff dilemma of technology and environment. In this paper, the main focus will be about how to implement a system-of-systems engineering approach design efficient energy and power management system for smarter cities.

2 Systems Engineering

A system is defined by the International Council on Systems Engineering (INCOSE) [22], as an artifact created by humans consisting of components that pursue a common goal unattainable by each of the single elements. This definition can lead to very broad generalizations or in-depth plans for an element. The engineering part of systems engineering represents the practice of employing tools and structured approaches to develop a product. Putting these two words together describes the SE practice of defining and documenting requirements for a product or process, preparing or choosing amongst design alternatives, assuring requirements have been met, and finally deploying, maintaining and disposing the system. The process is iterative, all the while employing optimization and streamlining the various elements to ensure that cost, schedule, and operational requirements are met.

Forsberg et al. [1] describe the “Vee” model relating systems engineering to the project cycle (see Figure 1). Design explorations and analyses are conducted at the start of the system development, ending with the complete integration and qualification of the finished system. The left side of the “Vee” model describes decomposition and definition activities; the center base represents the complete specification of system components, while the right side describes the quantitative verification activities assuring that requirements were met.

According to Ahram et al. [24], the contemporary SE process is an iterative, hierarchical, top down decomposition of system requirements [24,2]. The hierarchical decomposition includes Functional Analysis, Allocation, and Synthesis. The iterative process begins with a system-level decomposition and then proceeds through the functional subsystem level, all the way to the assembly and program level. The activities of functional analysis, requirements allocation, and synthesis will be completed before proceeding to the next lower level. Modeling SE Process Activity is performed using Systems Modeling Language (SysML). SysML is a general-purpose visual modeling language for specifying, analyzing, designing, and verifying complex systems which may include hardware, software, information, personnel, procedures, and facilities (http://www.omgsysml.org). SysML provides visual semantic representations for modeling system requirements, behavior, structure, and parametrics, which is used to integrate with other engineering analysis models [3]. SE teams along with system designers are responsible for verifying that the developed systems meet all requirements defined in the system specification documents.

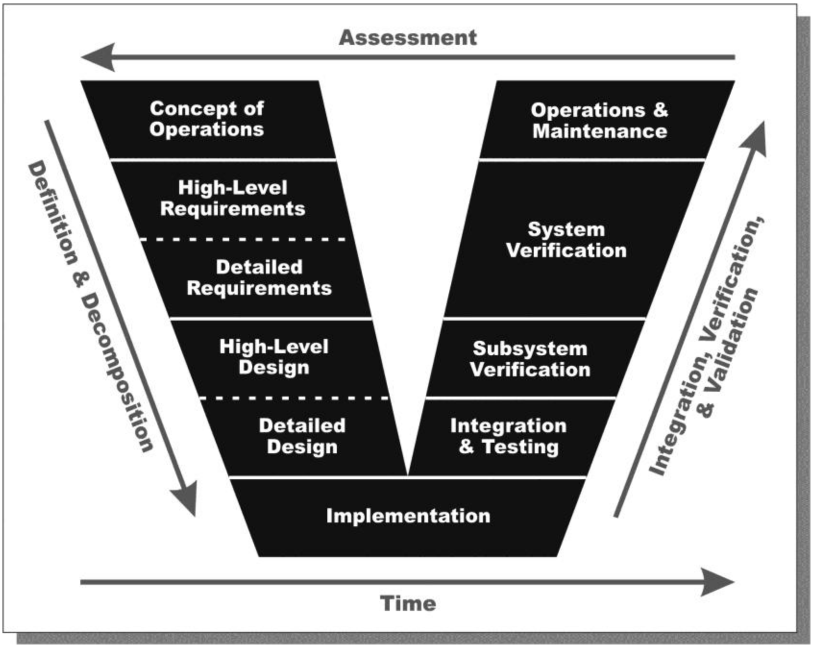

Fig. 1. Systems Engineering Vee Model [4]

The system-of-systems engineering approach for design and modeling of power generation systems differentiate between performance and effectiveness criteria [24]. These criteria determine a total system mission performance level and acceptability that is directly attributable to specific actions allocated to performance and efficiencies metrics. These are indicators measure which performance effectiveness criteria are met [5, 6]. The SE framework (see Figure 2) can be used to develop a system where the users and machine synergistically and interactively cooperate to conduct the mission of efficient power management and sustainability, and the "low hanging fruit" of performance improvement lies in the human–system interaction block.

As systems engineering (SE) practices unfold, problems inherently develop. These challenges are addressed using the systematic approach integral to SE practices and, once sufficiently addressed as defined by the agreed-upon requirements, the process moves on to the next phase and next problem [26]. The current standard used in industry and military applications is the EIA-621 standard. It applies to the product life cycle starting from the user needs to the final delivery. It outlines thirteen related processes divided into five functional groups.

Following systems engineering practices affords a formal design approach that attempts to cover all aspects of design. This includes a robust risk management portion that, given good requirements, will yield a safe design. Safety is not the only benefit of following this approach. Past performance on projects and previous research in systems engineering indicated that there is a positive correlation between utilizing formal systems engineering practices and the degree of success in an engineering undertaking, especially in return on investment (ROI) [7,5,8]. Today's difficult economy mandates a positive ROI on practically all undertakings and systems engineering practices assure that safety is not compromised.

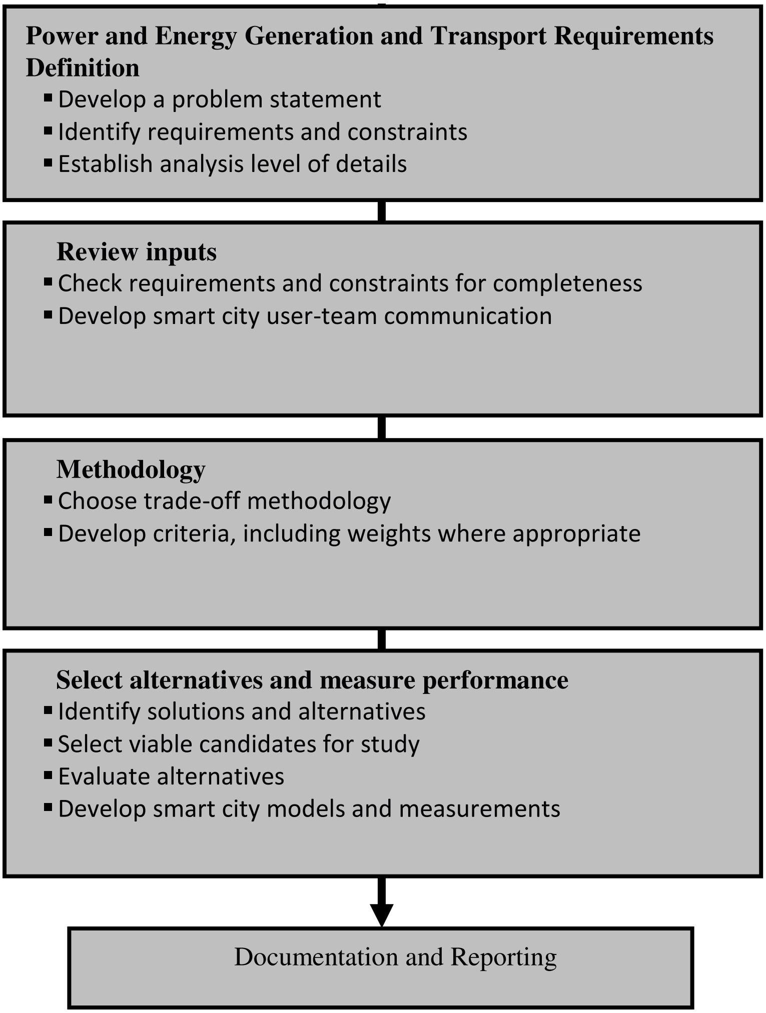

Fig. 2. The SE knowledge integration framework [24]

Profitability or on time delivery should never take priority over system safety and having a detailed plan based on systems engineering practices assures this does not happen. Ensuring a high ROI with a detailed plan on how to execute the design reassures management and moves projects forward [9].

Systems engineering also manages complexity. It is no secret that hardware and software is growing more complex with each passing year. New features are added, additional functionalities are created, and overall system complexity increases accordingly. Baumgart et al. [10] state that the implementation of new functions can actually lead to "inconsistent" systems. Their rationale is that in order to accommodate new functionalities technical architectures must be modified to compensate for these changes. Having a continuous, robust, reproducible design approach simplified matters greatly. This traceable, repeatable approach can increase overall levels of system safety through explicit visualization of system operations and identify possible breakdowns before they occur.

Another added benefit of a rigorous design framework is enabling concurrent design, where multiple projects proceed in parallel. These methods can also enable reuse of system components in new functions. These components can find new life by re-instantiation. This is especially true of software projects, however many modular physical components demonstrate this property as well. Systems engineering support identifying and assessing risk and help system designers and program managers develop proactive, cost-effective loss prevention programs that protect against loss, safeguard systems and operational continuity. Systems engineering assures that a life-critical support system behaves as needed even when components fail.

This merging of system components and functions was not possible until recent times. The design process must evolve to keep up with these new practices. The systems engineering practice comprises the following chain of artifacts: Processes → Methods → Tools. Processes are identified based on previous studies and general design heuristics, or from standards such as the EIA-632 standard. Methods can either be developed from scratch or recycled from past programs if they are applicable. The third item, tools, is concerned with methods involved in conceptual and detailed design; the tools are defined, acquired, or created once a viable method exists [11].

The overall goal of systems engineering is to convert user or stakeholder requirements into technical engineering requirements that drive design. Safety is always an important part of the requirement process, and is supported by the systems engineering framework through both validation of said requirements as well as verification that they have been met. Safety requirements generally set constraints on any given system. For example, safety requirements may mandate fall protection provisions, or set touch temperature on surfaces, or limit shift lengths. Safety requirements are hierarchical in nature with the most attention and consideration given to those of a critical nature or those needed even when components fail. Stakeholders, regulatory bodies, governing policies, or certification and quality standards may specify safety requirements. These requirements safety and loss prevention engineering may also be ordered and managed by a set of attributes. Software tools such as Systems Modeling Language (SysML) may aid in this venture [11].

3 Benefits of System Engineering for Energy Management

Systems engineering (SE) concepts and principles are an integral part of the contemporary engineered world [2] Such concepts are also used to create smarter consumer systems, protect human health, enable travel over great distances, and allow for instant and ubiquitous communication. These principles are also used to build energy efficient houses and transportation solutions, design workplaces, develop an infrastructure that society relies upon for smarter cities. The SE principles are used to make services and systems cheaper, more functional, and get them to the market faster. Systems engineers apply and integrate concepts and rules derived from math and science to create and apply such principles [12, 14, 15]. For example, the energy used to heat, cool, and light residential or industrial dwellings is typically generated hundreds of miles away from where it is used and needs to be transferred over long distances.

4 Power and Energy Smart Grid Revolution

Today, electricity is primarily generated at large, central fossil fuel plants and hydroelectric dams. It then travels hundreds of miles along complex network of transmission and distribution lines and devices that criss-crosses vast landscapes - called simply the grid. The electricity that powers everything from a single appliance to vast, intricate national systems is such an integral part of our daily lives that we rarely think about where it's made or how it's delivered.

In the near future, power generation and transmission need an even more complex and sophisticated infrastructure that will continue to power the digital economy but in a cleaner, more reliable, and more affordable way - a smart grid. Smart cities provide major economical and technological benefits to the nation and boost economy and jobs creation by implementing smart grid innovations [17]. According to the handbook for assessing smart grid projects [17,19], a smart grid will provide the following major benefits:

- Reduce peak demand by actively managing consumer demand
- Balance consumer reliability and power quality needs
- Mine energy efficiency opportunities proactively
- Improve overall operational efficiency
- Seamlessly integrate all clean energy technologies

5 Integration of Systems Engineering and Human Factors Knowledge Management into Energy and Power Generation and Transport

Knowledge management for smart cities and energy management is challenging [24], especially for large organizations with complex projects involving multiple disciplines. Despite the increasing ability to communicate and share knowledge, it seems that many designers and engineering groups do not share their findings outside of their own group [18, 26]. An often-encountered phenomenon is that of a "*Tribal Knowledge*", where a certain group or individual acquires a skill or trade and keeps it, employing it when called upon. Such groups rarely leave a legacy or ability to transfer this knowledge to their replacements, forcing the organization to relearn and human factors engineering groups and SE practitioners have realized the limitations and coined the term recreate that which it already knew [12].

The commercial market has already realized the importance of SE & human factors knowledge management, and thus a few software systems such as the *IBM Rational Focal Point*™ have been created to assist organizations and governments managing complex projects involved in designing and optimizing cities systems & infrastructure [26]. Figure 3 illustrate two *Focal Point*™ portfolios for smarter cities and smart energy and utility projects management. *Focal Point*™ supports SE, human trade-off analysis, data integration to optimize energy usage and maximize distribution efficiency.

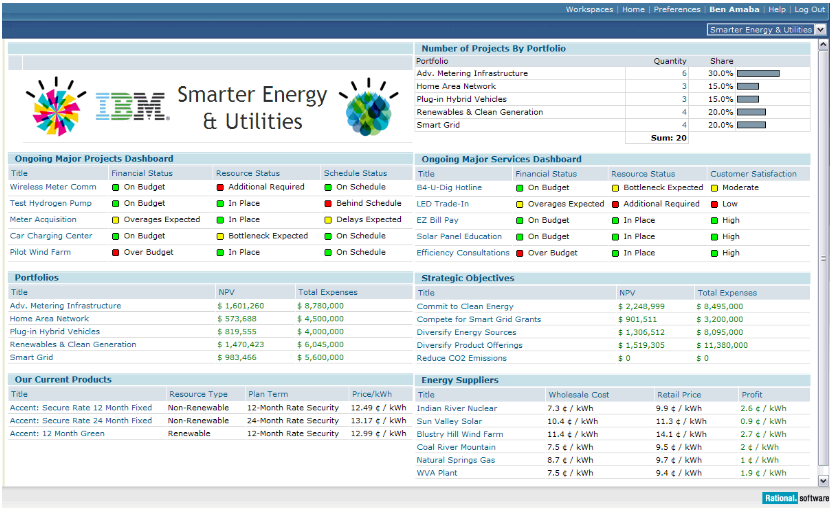

Fig. 3. Smarter Energy & Utilities network distribution projects management workspace. (Source: IBM Rational Focal Point™)

Successful practices for smart cities (software based on these practices) require the following features [6]:

- *Ease of use* – it is unlikely that something awkward or difficult to use will continue to be used in the long term
- *Varied format input* – aside from scribbling on notebook paper, the software should accept many document and file formats
- *Traceability* – inputs should be traced to their owner
- *Security* – all users may not require access to all elements of the knowledge database; proprietary, secret, and competitiveness concerns must be addressed
- *Routine* – inputs should be encouraged while the idea, solution, or process is still fresh in the creator’s mind

- *Organization* – without a structured method of entry or effective indexing method, acquired knowledge is meaningless; it should be viewable top-down, or searchable as browsable on varied related topics

6 Conclusions

Having a strong energy infrastructure changes how nations innovate, prosper, suffer or fade. Given the urgency of the situation, societies have to reuse, modify and apply best practices and technology to accelerate our ability to solve the energy famine on the horizon. History calls on an effective and battle tested systems engineering discipline that has supported putting people on the moon, space exploration, medical devices, airplanes, cellular telephones, nuclear reactors, and defense systems. This paper provides a motivation and quest for integrated systems engineering smart energy management approach. While a large number of disciplines and research fields must be integrated towards development and widespread use of smarter systems, considerable advancements achieved in these fields in recent years indicate that the adaptation of these results can lead to highly sophisticated yet widely useable collaborative user-centered applications for smart cities sustainability's. The SE and human engineering approach to design and modeling of smarter energy generation and transport systems prove critical l in supporting and facilitating the development and applications of future sustainable cities.

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The Effects of Early Training with Automation Tools on the Air Traffic Management Strategies of Student ATCos

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Abstract. The present study examined whether early exposure of student Air Traffic Controllers (ATCos) to NextGen automation technology in the form of integrated Data Comm affects the degree to which they come to rely on this tool instead of voice-based, manual tools to manage traffic. The data reported in this study comes from 24 students who took part in one of two semesters of an ATCo training course offered by our organization. One group received little or no early training with integrated Data Comm, managing no aircraft (AC) that were NextGen equipped or only 25% that were NextGen equipped in the first half of the course. A second group managed 75% aircraft (AC) that were NextGen equipped from the beginning of the training course. After the first half of the course, both groups received training with at least 50% NextGen-equipped aircraft (AC). Both groups were tested in a midterm and final exam that required them to manage traffic in a mixed equipage scenario. We found that proficiency of the students predicted their performance. Moreover, by the final exam, students converged on the same strategy, preferring to issue clearances using voice rather than Data Comm, regardless of early exposure to automation tools. This is likely because voice communication is faster than Data Comm, and is associated with greater efficiency of air traffic management.

Keywords: Reliance on automation, ATCo communication, ATC training, NextGen.

1 Introduction

The goal of the NextGen air traffic management system is to accommodate dramatic increases in air traffic density without simultaneously compromising the safety and efficiency of the National Air Space [1], [2] (NAS). In the current system, using manual tools that include radar displays and voice-based communications, Air Traffic Controllers (ATCos) can safely monitor and manage only about 15 aircraft in an en-route sector. As a result, a factor limiting the number of aircraft (AC) that can be operated in the NAS is the cognitive workload of ATCos. In particular, verbal

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 13–21, 2013.

communication has been cited as a main source of ATCo workload [3-5]. To prevent significant increases in workload, NextGen will incorporate new automation tools and technologies, ones that have the potential to significantly alter the roles and responsibilities of ATCos. These will likely include, inter alia, improved traffic and weather displays, automated conflict alerting tools, conflict resolution probing tools, and Data Comm. The latter allows clearances issued by ATCos to be uplinked to an AC without the need for verbal communication. Due to high implementation costs, the technologies that will form the core of NextGen are going to be introduced gradually, with the consequence that the NAS will contain a mixture of NextGen equipped and unequipped AC. This means that student ATCos will have to be taught to use both manual and NextGen tools. The present study examined how types of training with both types of technology affect the degree to which student ATCos come to rely on the new automation tools.

Very few studies have been conducted on how to train ATCos to use both manual and NextGen tools [6], [7]. In a study carried out with retired ATCos, for example, Kiken et al. [6] examined ATCos' performance after they were trained to manage a sector with only traditional, manual tools versus when they were trained to manage the same sector with NextGen tools. Kiken et al. found that ATCos' performance was more efficient (i.e., AC traveled less distance through the sector) when they managed all AC using manual tools, compared to when either some or all of the AC were equipped with NextGen tools. Of course, this benefit of using the manual skills could simply be due to the fact that the retired controllers were much more familiar with these traditional skills.

In Vu et al.'s [7] study, student ATCos were tested to see how best to train the use of manual and NextGen tools. In particular, they compared the benefits of using a part-whole vs. a whole-task training strategy. In the former, students learned manual skills first, receiving training on how to conduct "sweeps" of the radar scope to identify conflicts, how to generate resolutions, and how to issue verbal commands and instructions to AC using proper phraseology. Half way through the training course, (i.e., just before a midterm exam) they were introduced to NextGen tools. In contrast, the whole task group received training on both sets of tools from the very beginning of the course. They were tested for their proficiency at managing traffic in scenarios where either all AC were NextGen equipped, no AC were NextGen equipped, or where there was a mixture of the two. The results showed that more efficient traffic management occurred after practice with the whole, mixed-equipage air traffic environment. This held in particular when the student ATCos were of lower proficiency. For those that were of higher aptitude, the mode of training had less of an effect. Thus, the study supports the claim that it is important to take individual differences into account when devising training programs [8].

A central training issue is how to get ATCos to rely on technologies to a degree that accurately reflects their reliability and efficiency [9-11]. Indeed, training interventions have been developed to help encourage proper use of automation aids [12]. In the context of ATCo operations, potential NextGen tools have advantages and disadvantages over the manual, voice-based tools. For instance, with integrated Data Comm, where digital tools allow controllers to uplink route modifications directly into the (FMS) Flight Management System of the flight deck, the AC are automatically put back on their flight path after being routed for conflicts. With manual tools, ATCos have to remember to put AC back on their flight path, and it requires additional planning and communication to do so. Important drawbacks of Data Comm, however, include the fact that it is slower relative to voice, because it requires navigating computer menus instead of simply using a push-to-talk microphone. Furthermore, the ATCo does not receive an immediate acknowledgement of the clearance from the pilot, which is standard protocol with voice communications. These readbacks allow ATCos to make sure pilots are carrying out the appropriate actions, and doing so in a timely manner. Moreover, with voice communications ATCos can communicate the urgency of the clearance by including words such as "immediate" or "expedite." In short, ATCos need to weigh these costs and benefits when deciding which tools to use to manage traffic.

The present study examined whether the amount of early experience with the automation tools affects the likelihood that they will be relied upon by student ATCos to manage traffic. In particular, we examined the degree to which student ATCos use integrated Data Comm instead of voice communication to issue altitude clearances to AC as a function of how much early exposure they get with these tools. It is possible, for example, that reliance on automation is greater when students early on receive a substantial amount of training with these tools compared to when they receive less experience with these tools. Thus, whatever tools are emphasized early in training may determine which ones students come to depend on to manage traffic. However, it is also possible that although the early exposure to automation tools will increase their use early on, all students, regardless of type of training, will converge on the same strategies for managing traffic, reflecting their assessments of the relative merits of the tools. For example, if voice-based tools are overall faster and easier to use than integrated Data Comm, it is possible that despite an initial bias to use automation tools as a result of early exposure to them, student ATCos will nonetheless come to rely more on voice to issue clearances.

We also examined whether proficiency of the student controllers interacts with the type of training (more or less early experience with automation tools) to determine whether ATCos come to rely on voice or automation tools to issue clearances. It is possible, for example, that students who are more proficient at learning ATM skills are more likely to converge on the most efficient strategy for communicating with AC, while those who are less proficient may be more dependent on whatever tools they were exposed to first. Such a finding would be consistent with Vu et al.'s [7] study that found controllers who were less proficient were more affected by type of training than those who were more proficient.

2 Method

2.1 Participants

24 students enrolled in a local FAA CTI program participated in one of two semesters of a 16-week radar internship provided by the Center for Human Factors in Advanced

Aeronautics Technologies (CHAAT) at California State University, Long Beach. 10 participated in the first semester and 14 in the second semester. They were tested at the midterm, (i.e.) after 8 weeks of the internship, and again at the final, after 16 weeks of the internship.

2.2 Simulation Environment

The Multi Aircraft Control System (MACS) was used to simulate the radar display of Air Traffic Controllers (ATCos) managing Indianapolis Center (ZID) Sector 91. MACS is a medium fidelity environment that simulates traffic in ZID-91. It consists of arrivals and departures into Louisville airport, as well as overflights [13]. All AC were piloted by trained "pseudopilots" who provided a realistic traffic environment for the student controllers. Voice communication between controllers and pilots was provided by a voice server station via push-to-talk headsets for the unequipped AC and through Data Comm for equipped AC. The NextGen AC were equipped with:

- Integrated Controller-Pilot Data Comm. This allowed ATCo clearances and pilot requests to be delivered digitally; ATCo route modifications were integrated with the flight-deck's Flight Management System (FMS) and could be uploaded directly.
- Conflict Alerting. This tool alerted the ATCos to conflicts between two NextGen equipped aircraft within 6 minutes of a loss of separation.
- Trial Planner with Conflict Probe. It allowed controllers to graphically modify AC routes while probing for potential conflicts. Once the new route was identified, the ATCos could uplink the clearance to the flight deck using Data Comm commands.

2.3 Training Procedure

The participants in each semester's class were assigned to one of two groups. The training scenarios used for both groups differed in terms of the percentage of AC that were NextGen equipped during the first 8 weeks of training. Students in the "low early automation experience" group were trained to mainly rely on their manual skills, with either 25% of the AC in their sector being NextGen equipped (in the first semester), or 0% of their AC being NextGen equipped (in the second semester), with the remaining AC being unequipped. In both semesters, students in the "high early automation experience" groups had 75% of the AC in their sector equipped with NextGen tools, and 25% of the AC unequipped. Unequipped AC had to be managed with manual, voice-based tools. After week 8 of the course, (i.e.) the week before the midterm exam, both groups in each semester were trained using scenarios in which the equipage was 50%-50% and those who had no training with NextGen tools were introduced to the tools. In terms of conflicts, half of the planned ones in each scenario were between equipped and unequipped aircraft. As a result, controllers could choose to move either the equipped aircraft (using Data Comm) or the unequipped aircraft (using voice commands).

Students were trained to detect and resolve conflicts between equipped and unequipped AC using manual and NextGen tools. Failure to resolve a conflict resulted in a loss of separation. A loss of separation (LOS) was defined as two or more AC being within 1,000 ft vertically and 5 nautical miles laterally of each other. Students were trained to use 4 types of methods for avoiding and resolving conflicts: vectoring aircraft through heading changes, issuing altitude clearances, issuing speed changes, and structuring traffic flows (i.e., implementing corridors to a group of AC in a manner that would result in no conflicts between AC if structured properly). A student was considered a “Lab Journeyman” when s/he mastered all 4 skills by managing traffic in the sector without LOS using each skill. All students achieved this Lab Journeymen status by the end of the 16 weeks, but only some of them achieved this status by the midterm exam.

2.4 Testing Procedures

For both semesters, a midterm test was administered after the 8th week of training and a final test was run after the 16th week of training. The scenarios during the tests differed in the number of AC that were NextGen equipped, with 3 levels: 0%, 50%, and 100%. The order in which these scenarios were presented was counterbalanced between participants using a partial Latin square. In what follows, we present the results of the performance data during the midterm and final exam just for the 50% equipage scenarios. We limit the data to that scenario because we were interested in how the amount of early training with automation tools affects how students manage traffic in mixed equipage environments, (i.e.) whether this early experience increases or decreases their reliance on automation tools. The number of AC in the scenarios during each test was comparable between the two semesters, with each having between 16-18 equipped aircraft, and an equivalent number of unequipped AC.

3 Results

We recorded the number and type of clearances issued by controllers during their midterm and final exams, specifically examining the proportion of altitude clearances that they gave using voice vs. using Data Comm tools during each of these tests. We begin, however, by reporting whether behavioral measures pertaining to communication strategies can predict measures of ATCo performance.

Collapsing across midterm and final exams, we found that the total number of clearances that the student ATCos issued (regardless of type, (i.e.) heading or altitude, and regardless of modality, (i.e.) voice vs. Data Comm) was positively correlated with mean handoff accept time, $r = +.45$, $p < .001$, and with time to get aircraft through the sector, $r = +.39$, $p < .006$, two measures of sector efficiency. The more clearances they issued, the longer they took to take control over AC, and the longer it took AC to get through the sector. Greater numbers of clearances most likely extended the route taken by an AC through the sector, thus increasing time spent in the sector. Breaking down the total clearances into heading and altitude changes, we found that as the proportion of heading changes increased (relative to altitude clearances), the time it took to get aircraft through sector increased, $r = +.53$, $p < .001$, suggesting that altitude clearances led to more efficient traffic management by the student ATCos. However, the mode by which clearances were issued also predicted efficiency. Specifically, the proportion of heading changes issued by voice (as opposed to Data Comm) was negatively correlated with handoff give time, $r = -.34$, $p = .04$. For altitude clearances, as the proportion of altitude clearances issued by voice increased (and proportion of Data Comm clearances decreased), handoff give times decreased, $r = -.25$, $p = .09$. Thus, it appears as though greater numbers of clearances, especially heading changes, lengthened the time AC spent in the sector. However, managing traffic using voice-based manual tools was associated with more efficient traffic management. In what follows we examine whether amount of early training with automation tools affects the likelihood of student ATCos using voice vs. Data Comm tools.

To determine whether the communication strategy used by student ATCos was affected by type of training, a 2 x 2 x 2 x 2 mixed factors ANOVA was conducted on the proportion of altitude clearances issued by tools (voice vs. Data Comm), with testing session (midterm vs. final) as a repeated measures factor, and journeyman status at midterm (yes vs. no), early automation experience (high vs. low), and semester (first vs. second) as between subjects factors. Proportion of altitude clearances issued by voice was calculated by dividing the total number of altitude clearances issued by voice by the total number of altitude clearances issued regardless of modality (i.e., voice and Data Comm). This was done for the midterm and the final testing. Semester was included as a factor because, although the test scenarios had 50% equipage levels in both cases, the scenarios differed slightly in the number of aircraft at midterm and final. Furthermore, the two semesters differed in terms of the type of training participants received, with the low automation experience group in the first semester being exposed to 25% NextGen equipped aircraft for the first half of the course (and the high early automation experience group being exposed to 75% NextGen equipped aircraft from the beginning). In the second semester, those in the low automation experience group were exposed to no NextGen equipped aircraft for the first half of the course (and the high early automation experience group was exposed to 75% NextGen equipped aircraft from the beginning).

The results revealed a significant main effect of test, $F(1, 16) = 4.67$, $p < .05$, with ATCos issuing a greater proportion of altitude clearances by voice as opposed to Data Comm in the final exam ($M = .57$, $SE = .03$) than in the midterm ($M = .49$, $SE = .03$). Thus, the overall likelihood of using a communication strategy that is associated with greater efficiency increased from midterm to final testing. Importantly, however, the results revealed a significant interaction between test and early automation experience, $F(1, 16) = 5.22$, $p = .036$ (See Fig. 1). For those with little early experience with automation tools (being trained with either 0% or 25% NextGen equipped aircraft in the first half), there was no difference in the proportion of altitude clearances issued by voice at midterm ($M = .56$, $SE = .04$) and at final ($M = .55$, $SE = .04$), $F < 1$. They tended to prefer voice over Data Comm in both tests. For those with a high amount of early experience with automation tools (being trained with 75% NextGen equipped aircraft from the beginning), the proportion of altitude clearances issued by voice increased from the midterm ($M = .42$, $SE = .04$) to the final exam ($M = .59$, $SE = .05$), $F = 6.60$, $p = .033$. Thus, students preferred Data Comm at the midterm, but arrived at a similar preference for voice by the time of the final testing.

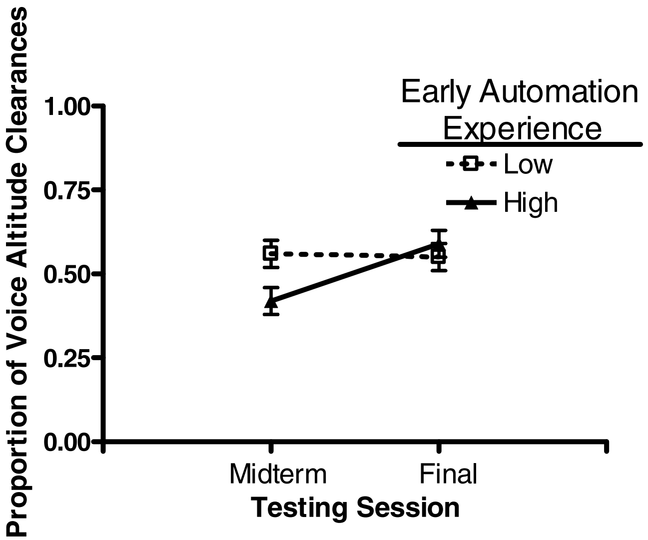

Fig. 1. Mean proportion of altitude clearances issued by voice as a function of testing session and early automation experience

The analysis also revealed a significant main effect of semester, F (1, 16) = 9.53, p = .007, with ATCo students in the first semester (half of whom overall had more experience with Data Comm tools) being less likely to issue altitude clearances by voice (M = .46, SE = .04) than students in the second semester (half of whom overall had less experience with Data Comm tools; M = .60, SE = .03). We also found a main effect of journeyman status, F (1, 16) = 6.21, p = .024. Student ATCos that were categorized as journeymen by the midterm were overall more likely to issue altitude clearances by voice (M = .59, SE = .03) compared to those not categorized as journeymen at midterm (M = .48, SE = .03). Thus, student ATCos that were more proficient at learning ATM tasks issued more altitude clearances by voice than Data Comm compared to those who were less proficient. No other main effects or interactions were significant at α-level of .05.

4 Discussion

We found that amount of clearances issued by student ATCos affected their workload, because as the number of clearances increased, the efficiency with which ATCos managed traffic decreased. Furthermore, the type of clearances that they issued affected efficiency, with altitude clearances being associated with greater efficiency and heading clearances with greater inefficiency, as revealed by differences in time through sector, and handoff accept times. Furthermore, using voice communications instead of Data Comm to issue clearances was associated with greater efficiency with which student ATCos managed traffic.

The main goal of our study was to examine how type of training affected the reliance on the automated integrated Data Comm tool, instead of the more efficient, but manual, voice communications to manage traffic. We found that although there was a slight advantage in favor of Data Comm in the midterm, students came to rely on voice communications to issue altitude clearances by the final exam. One likely factor is that once it is mastered, voice is much faster than Data Comm, which would make it a more efficient strategy with which to manage traffic. It is also possible that the greater reliance on voice stems from the fact that it is seen as a more basic and essential skill by student controllers. Voice based traffic management, with its complex phraseology and rules for issuing clearances, may be more difficult to learn at first, and may be seen as requiring more practice by the student controllers, contributing to their greater reliance on it by the final exam. This interpretation is also supported by the fact that the more proficient students, those classified as journeymen by the midterm, also tended to prefer to issue altitude clearances by voice.

Importantly, we also found an interaction between amount of early experience with automation tools and test session. Those students who received very little or no early exposure to the automation tools had a consistent preference for using voice. In contrast, those with considerable early experience with the automation had a small preference for using integrated Data Comm in the midterm, likely because of the difficulty in learning voice based traffic management. However, by the final they, too, acquired a preference to use voice commands to issue altitude clearances. Therefore, in the long run, their early exposure to automated technologies did not affect the strategy with which they managed traffic. Both groups converged on the same preferences to manage traffic by using voice-issued commands.

To conclude, we found that although differences in student proficiency account for overall differences in reliance on voice vs. Data Comm, the type of early exposure to automation tools is not as important. Regardless of how much early experience students acquired with the automation tools, they converged on an overall preference to issue clearances with voice based tools.

Acknowledgments. This project was supported by NASA cooperative agreement NNX09AU66A, Group 5 University Research Center: Center for Human Factors in Advanced Aeronautics Technologies (Brenda Collins, Technical Monitor).

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Intuitive Gestures on Multi-touch Displays for Reading Radiological Images

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Abstract. Touch-based user interfaces are increasingly used in private and professional domains. While touch interfaces have a high practicability for general daily applications, it is a central question if touch based interfaces also meet requirements of specific professional domains. In this paper we explore the applicability of touch gestures for the domain of medical imaging. We developed a set of intuitively usable gestures, applicable to different screen sizes. The development was entirely user-centered and followed a three-step procedure. (1) The gesture set was developed by asking novices to propose possible gestures for different actions in medical imaging. (2) The gesture set was implemented in a commercial medical imaging solution and (3) evaluated by professional radiologists. The evaluation shows that the user-centered procedure was successful: The gestures did not only work equally well on different screen sizes, but revealed to be intuitive to use or easy to learn.

Keywords: Multi-touch, gestures, medical imaging, radiology, intuitiveness.

1 Motivation

Multi-touch displays are a widespread technology for consumer products like mobile phones and tablet PCs. These devices host a variety of applications which are primarily used in common, everyday scenarios, such as internet browsing, messaging, photo viewing, etc., and are widely accepted and appreciated. The usage of multi-touch for highly specialized professional applications is not trivial but for each specific application field the most frequently performed interactions in the specific scenario need to be translated into common multi-touch gestures. Also, it is not clear whether multi-touch interactions are appropriate for performing highly specialized tasks which may have different requirements on efficiency, precision, and accuracy than the above mentioned "everyday" tasks. In the field of radiological imaging there is a high interest of professionals in accessing their cases from anywhere in order to be able to provide expert feedback in all types of situations, e.g., when being asked for advice by a colleague via telephone, in a clinical conference (tumor board) or when explaining the diagnosis to patients. Therefore, the usage of tablet PCs or smart phones seems to be a valuable option. However, no standards exist on how to translate the most important

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 22–31, 2013.

functionalities for the interaction with radiological images to multi-touch gestures. Since radiologists often use different software from different vendors to read their cases, it would be a great benefit for this user group if medical vendors agreed on a standard for the multi-touch gestures because this would enable them to use different devices and applications without transition costs. Also, from a cognitive ergonomic point of view it is not clear whether it is possible to identify a uniquely prototypic gesture set that meets medical professionals' needs regarding the expressiveness of gestures in form and content, and is also intuitive to use and easy to learn. This paper presents an empirical study that evaluates multi-touch gestures for the interactions needed when reading radiological images.

2 Method

To develop and test an intuitive gesture set for interacting with medical images we used an iterative empirical-experimental approach: First, we identified intuitive gestures by letting non-radiologists perform possible gestures on a paper prototype. Second, we identified common features among the gestures and compiled these into a complete gesture set. Third, we asked two medical professionals for applicability of the gesture set. Fourth, the gesture set was implemented into a professional imaging solution and radiologists as well as non-radiologists evaluated the gesture set on three different display sizes. The functions required for interacting with medical images are closely related to the physical form of data and the requirements of the radiologists carrying out the diagnoses. Hence, we will briefly introduce the very basics of medical imaging before we detail the empirical procedure.

2.1 Radiological Imaging and Frequently Used Functions

Medical imaging is the technique and process used to create images of the human body (or parts and function thereof) for clinical purposes (medical procedures seeking to reveal, diagnose, or examine disease) or medical science [4]. Radiologists have the task to review and interpret 2D, 3D or 4D (3D data acquired over a period of time) images. Due to the high amount of imaging data produced by state-of-the-art radiological imaging technologies like computed tomography and magnetic resonance imaging, radiologists need efficient techniques to visualize (e.g., in different planes or as volume), manipulate (e.g., change contrast and brightness) and navigate (e.g., scroll through stacked images or rotate volumes) the image data provided. There are uncountable functions in professional medical imaging solutions. For this work we focused on the most commonly used functions and operations that professional radiologists use in their daily work. Radiologists typically work with both two-dimensional and three-dimensional image material.

For two-dimensional images the most frequently used operations are: *Zoom and Pan, Scrolling through a Stack*, and *Windowing (changing brightness and contrast).* The zoom operation allows radiologists to magnify a specific area of an image, whereas the pan operation allows changing the viewport of the given image. The scrolling through a stack operation is used to display different layers of the current image. With this operation radiologists are able to scroll along the axis orthogonal to the display. Radiologists require two types of scrolling: exact / step-wise scrolling (e.g. next/previous layer) and quick scrolling (e.g., to quickly scan the abdominal area for malign tissue).

For three-dimensional material the most often used operations are *Rotating a Volume* and also *Zoom* and *Pan*. *Pan Zooming* and *Panning* 3D images is equivalent to the 2D case. For both two- and three-dimensional images the material is usually displayed in a grid of multiple windows (e.g., one window showing a 3D image, and one window for 2D views in different orientations (e.g., sagittal, coronal and axial plane). The *Blow-up* and the *Blow-down* operations are used to display one of these image segments maximized or to restore the previous grid view.

2.2 Generation of a Gesture Set

To extract intuitive gestures for interacting with medical images we recruited 14 unpaid participants (8 male, 6 female) for a user study. None of them had any experience in medical imaging or medicine. Also, some of the participants had little expertise with touch displays, such as smart phones or tablet devices.

We first gave a brief overview about radiology and the frequently used functions as described above. After that we also presented videos of the effect of each function, in order to support the understanding of the functions and their effects on the displayed images. The participants had the opportunity to ask questions or review the videos at any time. The participants were then asked to perform each gesture on a paper prototype of a medical imaging solution. We monitored the hand and finger movements of the participants with a camera attached to the participant's chest. The approach of presenting the desired outcome of a gesture and letting users perform possible actions is similar to the one used by Wobbrock et al. [3].

All participants had to perform the gestures in the same order (first 2D gestures, then 3D gestures). Each participant performed the gestures twice: once on a small size display (phone-size or tablet-size) and once on a wall-size display (*24"* or *48"*). The size and the order of the paper prototypes were randomized across the participants. After the experiment the performed gestures were classified. Hereto, we first developed a categorization scheme by viewing the video recordings, discussing common features, and defining a set of gesture categories for each gesture. The categorization scheme includes multiple dimensions such as the number of fingers or hands involved or the type of gesture performed.

After that two researchers independently reviewed the material and classified the gesture executions accordingly. We classified the proposed gestures according to the classification scheme. Only rough estimates of the number of mentions will be reported as not all proposed gestures fit in exactly one category. In the following we use the terms *frequently*, *commonly,* and *rarely* for propositions that were made respectively by over *2/3*, *1/3* to *2/3* or less than *1/3* of the participants.

Scrolling through a Stack: Frequently, participants proposed a gesture that utilizes an imaginary scrollbar at the side of the screen (similar to a finger on a telephone book page). Also *frequently* suggested was a swipe gesture in which a finger (small screen) or hand (large screen) was slowly moved across the surface. *Commonly* suggested was a flick gesture in which a finger/hand was rapidly moved across the surface.

Zoom: For zooming participants *frequently* proposed a pinch to zoom gesture. It was either performed with two hands on large screens or with two fingers on small screens. Other *rare* suggestions were opening and closing the hand (all fingers involved) and using a button instead of a gesture.

Pan: Participants *frequently* suggested a tap-drag gesture. However, they disagreed regarding the number of fingers/hands to use. Roughly half of them suggested using one finger/hand, whereas the other half suggested using two. *Rarely* suggested was a gesture that uses the whole flat hand to pan an image on large screens.

Windowing: A variety of gestures were proposed for this function. *Commonly* suggested were a set of two sliders, either visible on demand or permanently on screen (comparable to the set of scrollbars on desktop systems). Another gesture also *commonly* suggested was opening and closing the hand (described as rising and sinking sun). However, this gesture offers only 1 instead of the required 2 degrees-of-freedom. A tap-drag gesture on a 2 dimensional plane was *rarely* suggested: Dragging along the horizontal axis changed the window width and dragging along the vertical axis changed the window height. Again *commonly* proposed was the use of a menu button instead of a gesture.

Rotating a Volume: *Frequently,* the participants fixated a point with a finger (small screen) or hand (large screen) on an imagined sphere and rotated that sphere by dragging the finger/hand over the surface. Thus, novices proposed a gesture that resembles the popular *ARCBALL* technique by Shoemake [2]. Separate buttons for rotating the object instead of a gesture were proposed only *rarely*.

Blow-up and *Blow-down*: *Frequently,* a double tap gesture was proposed that either expands the segment in which it was executed or reverts from full screen to the previous state. A *rarely* made suggestion was a tap-drag gesture that moves the segment to be maximized to the center of the screen.

Overall, the proposed gestures were basically the same for small and large displays, showing that radiological gestures are generally prototypic. The only notable difference is that gestures were performed with the whole hand on large displays whereas the fingers were used on small size displays. With the exception of the *Windowing* function, on the whole, the participants proposed the same gestures for each of the different functions in medical imaging. Thus, we can assume that we have found a gesture set that is intuitive and universal for different display sizes.

2.3 Cross-Validation of the Generated Gesture Set

Users who had no knowledge of medical imaging proposed the gesture set. Thus, before the gestures were implemented into a functional prototype and before a formal user study with radiologists was carried out, we gathered professional feedback from two radiologists that was, in general, positive. However, they criticized the lack of a common gesture for the *Windowing* function and they coherently suggested a tap-drag gesture that adjusts the window width and height by dragging the finger along the axis. We therefore continued with the implementation and formal evaluation of the gestures and their universality across different display sizes.

The gestures for *Windowing*, *Scrolling through a Stack*, *Blow-up* and *Blow-down*, *Pan* and *Zoom* and *Rotating a Volume* were implemented as shown in Figure 1.

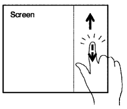
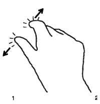
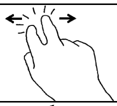
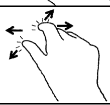
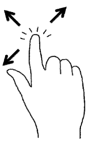
	*Windowing:* To change the window (brightness and contrast), a tap-drag gesture has to be performed. Moving the finger vertically changes the image's brightness. Moving the finger horizontally changes the contrast.
	*Scrolling through a Stack: Flick:* To scroll though the images layer by layer, the *flick* gesture can be used. A finger has to be placed on the surface and quickly moved up- or downwards and released immediately from the surface. In contrast to the scrollbar (see below) this gesture can be performed anywhere on the image.
	*Scrolling through a Stack: Scrollbar:* The scrollbar can be used to quickly skim through the image stack. For this the finger has to be placed on the right hand side of the image and moved up- or downwards.
	*Blow-up / Blow-down:* To perform a Blow-up or Blow-down (activate/deactivate full screen-mode for an image segment), a double tap has to be performed.
	*Zoom:* To enlarge the image, two fingers must be placed on the surface. Then the increasing or decreasing the distance of the fingers will enlarge or shrink the displayed image.
	*Pan:* To pan an image, two fingers have to be placed on the surface. If the fingers are moved the image is panned in the same direction and speed.
	*Zoom and Pan:* It is possible to perform the gestures for zoom and pan simultaneously.
	*Rotating a Volume:* To rotate a 3D-model, a single finger has to be placed on the surface. On an imaginary sphere, the finger fixates a point. By moving the finger, the sphere is rotated with the point and the finger linked together.

Fig. 1. Generated multi-touch gesture set

2.4 Evaluation of the Gesture Set

A development release of a medical imaging software[1] was modified to support touch events. One research goal was to identify gestures that are universal to different display sizes. Therefore we tested the gesture set on multiple display sizes: a 4” mobile phone display, a 10” tablet display, and a 60” wall-sized display. In the following the three sizes will be referred to as *phone-size*, *tablet-size* and *wall-size*.

2.4.1 Experimental Setup

In the experiment, we evaluated the gestures as well as three different display sizes. The order of the display sizes was randomized across the participants. The gestures had to be performed in a fixed order: First 2D gestures and then 3D gestures. The gestures were performed as part of a mock medical diagnosis. For example, to evaluate the *Windowing* gesture, the radiologists were asked to modify the window setting to investigate first the lung, then soft tissue. In addition to the study of isolated gestures, participants also had to perform two complex tasks (one 2D, one 3D) in which all gestures had to be used. Participants had to rate each gesture according to its intuitiveness, perceived ease of use, learnability, precision, and efficiency. In addition to the gesture ratings by participants, a post-hoc video analysis of the gesture executions was accomplished as external validation in which an expert evaluated the intuitiveness, ease of use of the gestures, and the kinds of errors that occurred.

After the experiment, the participants rated each display size for its suitability for medical diagnoses, the overall quality of the display, the precision, and the intention to use touch-based displays in medical imaging. Figure 2 shows a user performing a *Zoom* gesture on the wall-sized display.

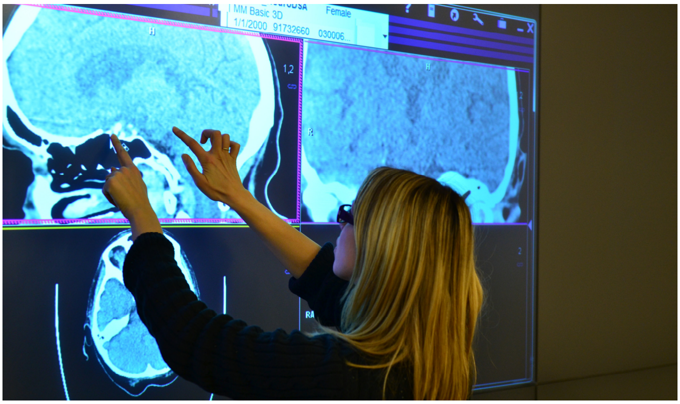


Fig. 2. A user performing a *Zoom* gesture on the wall-sized display

[1] *syngo*.via from Siemens Healthcare was used for evaluation. The software is a medical imaging product for radiologists offering routine and advanced reading functionality for multiple modalities like MRI, CT and PET-CT.

2.5 Results

Due to the comparably small number of participants, we report on descriptive outcomes rather than inference statistics.

In total, 24 participants (50% women, 50% men) took part in this study. 13 were professional radiologists (in the following called *experts*) and 11 subjects had no experience in radiology or medicine (called *novices*). As experts were the main target group for the application to be developed, we concentrate on the insights gained from observing the experts. Findings from the novices will be reported where appropriate. On average, experts had 13 years of work experience (5 had more, 8 had less than 10 years of professional experience). 6 participants stated that they have made more than 100,000 diagnoses, with another 3 reporting over 10,000 diagnoses so far.

Gesture Set. The gesture executions were assessed by a post-hoc video analysis. For each gesture the number of help cues was counted and the perceived ease of use was rated.

The observed intuitiveness was in general high for all but the two *Scrolling through a Stack* gestures. The participants executed over 90% of the requested gestures without additional cues from the examiners. Especially the combination tasks were completed without significant help. Yet both gestures for *Scrolling through a Stack* show room for improvement. The *Flick* gesture was used intuitively in only 43% of the trials and in 14% of the trials more than one cue from the examiners was needed. The *Scrollbar* performed better: 74% of the trials were done correctly without any cues. Still, in 11% of the cases more than one cue was necessary (see Figure 3). These findings conform to the observed ease of use during the gesture execution that was also high for all but the two *Scrolling through a Stack* gestures. Additionally, we observed that the participants frequently performed *Windowing* instead *Panning*; both gestures were designed as a tap-drag gesture (the former with one finger, the latter with two fingers). Both combination tasks (diagnoses with multiple gestures) were performed without additional help by almost all participants (see Figure 3).

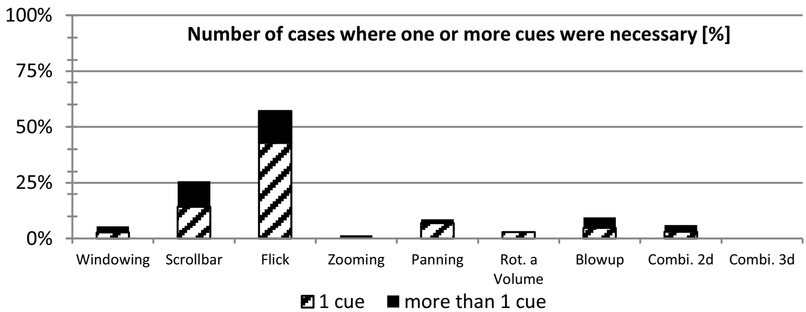


Fig. 3. Observed intuitiveness for gesture executions

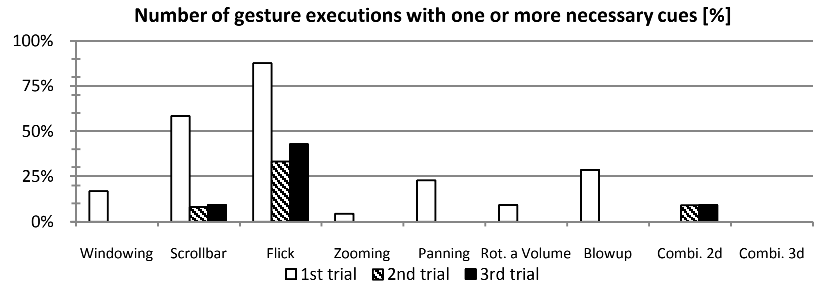


Fig. 4. Learnability of the gesture set

Based on these findings we investigated the learnability of the gesture set, i.e., we studied for each gesture whether the number of cues needed decreases with the number of trials. Indeed, for *Windowing*, *Zooming*, *Panning, Rotating a Volume* and *Blowup* gestures, cues were only necessary during the 1st trial. In later trials, all participants executed the gestures without additional support from the examiners.

In the 1st trial, the *Scrollbar* gesture required external cues in 58% of the cases. This drops to 9% for the 3rd trial. The number of necessary cues for the *Flick* gestures drops by factor two between the 1st and the 3rd trial. Although this proves a tremendous learning effect, there are still 43% gesture executions that were not performed autonomously by the participants (see Figure 4).

Display Sizes. The rating of tablet-size outperformed the rating of phone-size and wall-size in every dimension (see Figure 5). The intention to use a touch-based medical imaging solution was highest for the tablet (on average +33 points on a scale from -100 to +100), followed by the phone (-20 points) and the wall (-22 points). Likewise the expected usage frequency was highest for the tablet (+61 points); in contrast, phone-size (0 points) or wall-size (-27 points) were rated rather low. *Novices*, however, rated the wall-sized display highest, followed by tablet and then phone. We argue that they might have judged from the patient's perspective and that they might prefer the large display for doctor-patient-communication as they did in other studies [1].

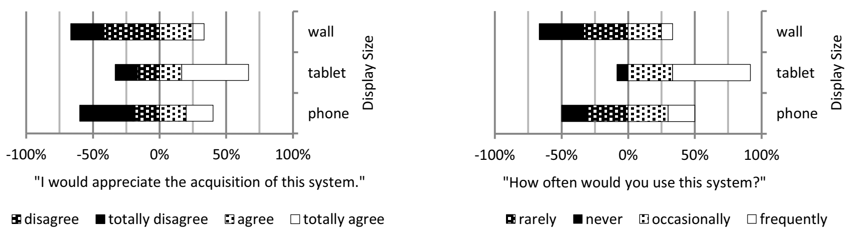


Fig. 5. Desire to use and expected usage frequency dependent on display size

The evaluation of the phone-sized display dominated the wall-size in all but one dimension: the adequacy of screen size. On the phone the available screen space is regarded as insufficient for diagnoses. Radiologists stated that a tablet might be more useful for discussing the findings with patients than doing the actual diagnosis. They dislike using a phone for this purpose as they consider the displays too small.

Touch-Based Interaction in Radiology. Participants had to indicate before and after the experiment whether they would use touch-based interaction for their daily routine and whether they judge touch-based interaction useful in the domain of radiology. At the beginning, the desire to use touch interaction for diagnoses was high (M = 48 points on a scale from -100 to 100%) and increased by 59% to 76 points after the experiment. The perceived usefulness of touch interaction was equally high (48 points) and grew by 31% to 63 points (see Figure 6).

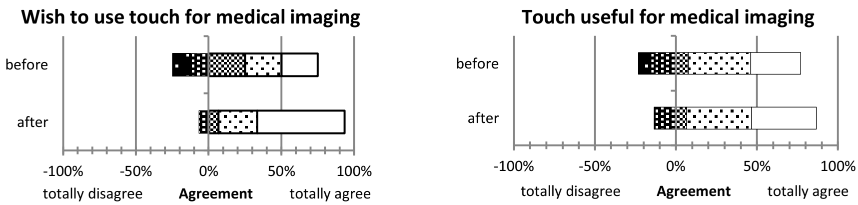


Fig. 6. Intention to use touch displays before and after the experiment

3 Discussion and Future Work

Overall, the study showed that touch-based interactions are a highly promising interaction mode, even in specialized professional areas such as medical imaging. We could reveal that there are prototypic gestures which are perceived as useful by medical professionals. Therefore, the findings represent a promising basis for the development of a standard for multi-touch gestures. A noteworthy finding is that all medical professionals were even more enthusiastic about the usefulness after they had worked with the system. This shows that any evaluation of novel systems profits from real, hands-on experience and confirms the adequacy of user-centered approaches in technical developments. In addition, medical professionals were not only highly willing to contribute to the development in this specific medical domain, but were even glad to provide their professional point of view before a system is marketed.

Display sizes: In general, the large multi-touch wall was evaluated as insufficient: The participants disliked the rather low pixel density and the too large information display. Most criticized was the low precision when interacting with the device. This is caused by our technical setup which is prone to errors due to the use of computer vision, network latency, and the interplay of multiple computers. However, novices liked the large display more than the other sizes. The mismatch between the medical professionals' and the novices' evaluation of the suitability of the wall-sized display might be based on the different perspective (medical professional vs. patient). The tablet-size is evaluated very well and dominated the phone- and wall-sized display in subjective ratings as well as in error metrics. Still, we noticed that participants with long work experience also appreciate the phone-sized display. Interviews revealed that they appreciate the small display for being able to perform diagnoses remotely.

Gesture set: The developed gesture set for interacting with medical data is intuitive and easy to learn. Furthermore, it is suitable for various display sizes, such as smart phones, tablets, or wall-sized displays. Still, two gestures show potential for improvement: Both gestures for *Scrolling through a Stack* were not intuitive as their correct execution required external help. The *Scrollbar* has shown great learnability and is remembered after the first trial. The *Flick* gesture also showed a strong learning effect, but some participants had difficulties recalling this gesture even after the 3rd trial. In addition, we learned that the gestures for *Panning* and *Windowing* are conflicting. Both were implemented as tap-drag: *Windowing* with one finger, *Panning* with two fingers. Participants frequently mixed up both gestures in the beginning.

Thus, the task of creating a *completely* intuitive gesture set could not be achieved in this study. Nevertheless, we have developed a gesture set that was *mostly* intuitive and non-intuitive gestures were easy to learn. Especially, combination tasks, which reflect the work practice of radiologists, were performed without any difficulties.

Overall, the study has shown the high acceptance of multi-touch gestures for interaction with radiological images. The gesture set, however, should be re-evaluated under more stable technical conditions and in a set-up that better reflects the radiologists' work situation. Also, it is planned to evaluate how this gesture set can be extended to non-contact interaction which would be beneficial for interventional radiology and surgery where images need to be manipulated in a sterile environment.

Acknowledgements. Thanks to all participants, but especially the medical professionals, for their time and willingness to share their professional view with us. Thanks also to Luisa Bremen, Tatjana Hamann, Eva Dickmeis, Felix Heidrich, Chantal Lidynia, Oliver Sack, Andreas Schäfer, and Frederic Speicher for research assistance.

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Pathway Construction and Extension Using Natural Language Processing

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Abstract. Construction and maintenance of signaling pathway is a time-consuming and labor-intensive task. In addition, integration of various pathways is also ineffective since several markup languages are used to express pathways. To overcome these limitation, automatic pathway construction and extension with a standard format may provide a solution. The proposed approach has constructed a gold standard corpus that describes the signaling pathways, and it has been used to training and evaluating the automatic pathway construction and extension. Moreover, a standard format to express the signaling pathways has been developed and has been used to express the previous major 10 signaling pathways. An effective visualization tool has been also developed for the standardized format as well. The visualization tool can help to construct pathways and extend the current pathways using all articles in PubMed.

1 Introduction

The signaling pathway indicates a group of molecules in a cell that work together to control one or more cell functions. Such pathways specify mechanisms that explain how cells carry out their major functions by means of molecules and reactions. Since many diseases can be explained by defects in pathways, information from pathways provides useful source to develop new drugs. There are some limitations in construction of pathways. (1) Mostly pathways are constructed by manual methods. Biologists have to read many articles and construct a pathway. (2) The curation of a constructed pathway also requires regularly monitoring of up-to-date publications. (3) The number of publicly available pathways is not sufficient and many useful pathways can be used after paying expensive license fee. (4) Since there is no standard format to express pathways even though there exist popular description formats, a total search is difficult. Automatic pathway construction and extension may overcome these limitations in the pathway construction and maintenance.

2 Related Work

Kyoto Encyclopedia of Genes and Genomes (KEGG), one of the major pathway databases, provides a lot of metabolic and signaling pathways and all pathways

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 32–38, 2013.

Fig. 1. Event ontology

are expressed by KGML format [2]. Reactome contains 1,300 human pathways related with metabolism, signaling, gene regulation, and other biological processes and pathways in Reactome are provided by SBML and BioPAX format [3]. SRI's BioCyc consists of EcoCyc, MetaCyc HumanCyc and BSubCyc, and the number of pathways is 361, 2142, 303 and 279 respectively. SBML, BioPAX are the method to describe pathways [4].

All pathway databases in the previous work are popularly used in various applications and the most process of pathway construction have been done by a manual method. In addition, since all pathway databases have not been integrated, they cannot be searched at one time and they have constructed the pathways that are partially same pathways with other pathway databases. We aim to integrate pathways that are described with various expression methods and develop an automatic pathway construction and extension system.

3 Construction of a Gold Standard Corpus

To construct and extend pathways automatically, a gold standard corpus has been constructed. Types of annotation are as follows: (1) Target entities contain protein, gene, chemical compound and complex. (2) 24 target relations (1) have been selected from Systems Biology Ontology with respect to relations in the signaling pathway.

Fig. 2. An annotation example

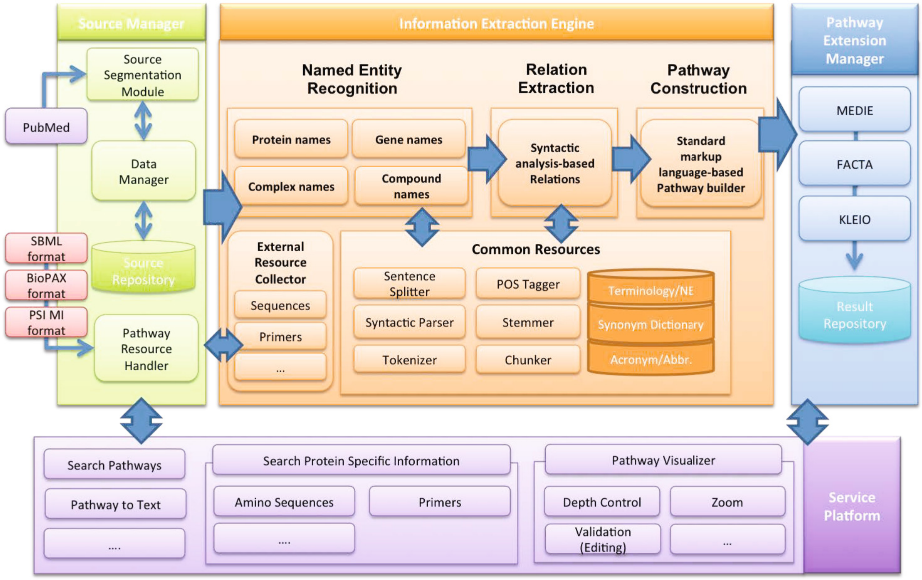

Fig. 3. Architecture of Pathway Construction and Extension

Figure 2 describes an annotation example. Brat version 1.3 had been used to annotate the gold standard. It is popular in the field of natural language processing and effective to express entities and their relations. 570 PubMed abstracts were selected with respect to p53, NF Kappa B that were popular issues in the biomedical domain. Four annotators have participated in the tasks of recognition of entities and their relations. The inter-annotator agreement were calculated by F-measure that is one of the popularly used method for the structured data, and showed 61.0%. One annotation result was regarded as the gold standard and other three annotation results were evaluated in each iteration. Four F-measures were calculated by four times and their average was calculated.

4 Pathway Construction and Extension

To construct and extend pathways automatically, natural language processing-based text mining techniques were applied. Figure 3 describes the system architecture for pathway construction and extension. Meaningful biomedical information was recognized and extracted from PubMed abstracts. Machine

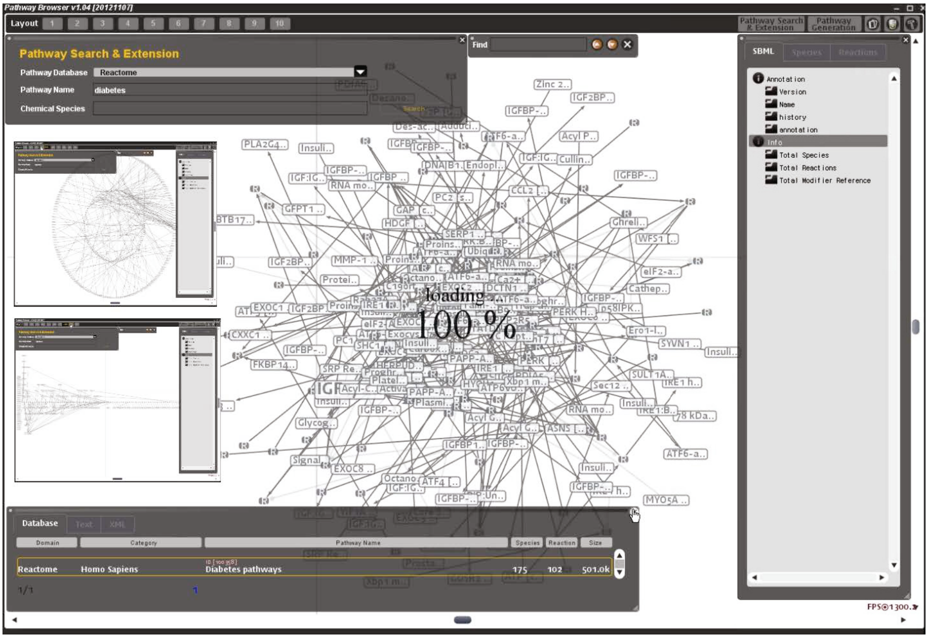

Fig. 4. Pathway Browser

learning technique-based *Named Entity Recognition* [5] and *Relation Extraction* [6] [7] [8] are used, and pathways have been constructed based on the extracted entities and their relations. All pathways constructed in the proposed approach are expressed by a standard markup language. To extend a part of a current pathway, all current pathways were converted the standard markup language. *Pathway extension manager* provides the evidential contexts that support to explain a part of pathways or a whole pathway. The collection methods of the evidential contexts include MEDIE [9], FACTA [10], KLEIO [11]. *Common Resources* are useful techniques and data to recognize entities and their relations, and Natural Language Processing (NLP) tools such as a sentence splitter, a syntactic parser [12] as well as language resources such as technology dictionaries, synonym dictionaries, verb dictionaries, acronym dictionaries, relation pattern dictionaries. The common resources are used in both NER and RE part. Pathway search, advanced search for proteins, and pathway visualization would be possible services in the *Service Platform.*

To visualize pathways, a effective network browser were developed (Figure 4). There are two functions: (1) Pathway search and extension; (2) Pathway generation. A keyword search is possible in the pathway search and extension service. To improve readability and in the point of information delivery, 10 visualization types were applied. Information of species and their hierarchy is displayed in the right panel.

Figure 5 describes the automatic pathway extension with two species (ATP and ADP) in the current pathway. More species selection makes to search more

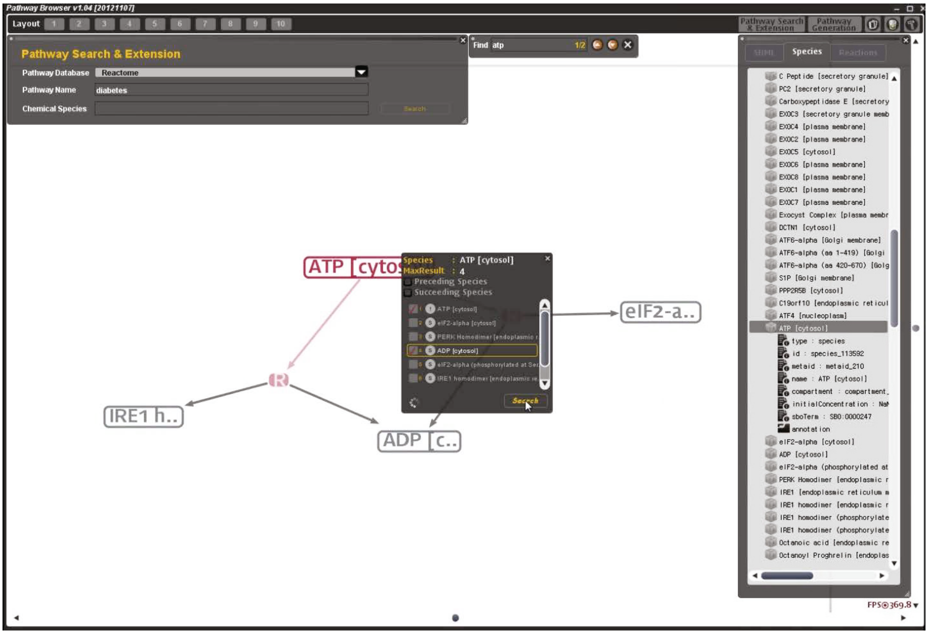

Fig. 5. Architecture of Pathway Construction

specific and perfect candidate pathways. Figure 6 shows the results of the pathway extension in Figure 5. Four groups indicate four different PubMed abstracts and the each abstract can be checked. Each species or each abstract can be easily removed by "Delete" button in the keyboard. From the provided candidates, users can select the right pathways.

The result of the automatic pathway generation using one or more species is the same with Figure 6. The difference is that the pathway generation is started with one or more species that users are interested in.

5 Standardization of Pathway Markup Language

The proposed approach uses Natural Language Processing (NLP) techniques to recognize and extract knowledge from biomedical literature. From news articles, magazines, patents as well as PubMed articles relations among protein, gene, chemical compound, complex are extracted and integrated those knowledge into the existing pathways that are expressed by various formats containing SBML, BioPAX, PSI-MI formats. Based on relational knowledge pathways can be constructed. Currently, 10 pathway databases are integrated: *Reactome, Human Cyc, Panther, Signal Link, SABIO-RK, PharmGKB, KEGG, BioModels, HPRD* and *DIP*. Table 1 describes various pathway markup languages for pathways.

The various pathway description methods is ineffective to integrate knowledge in the various pathways. Many similar pathways have been constructed since the

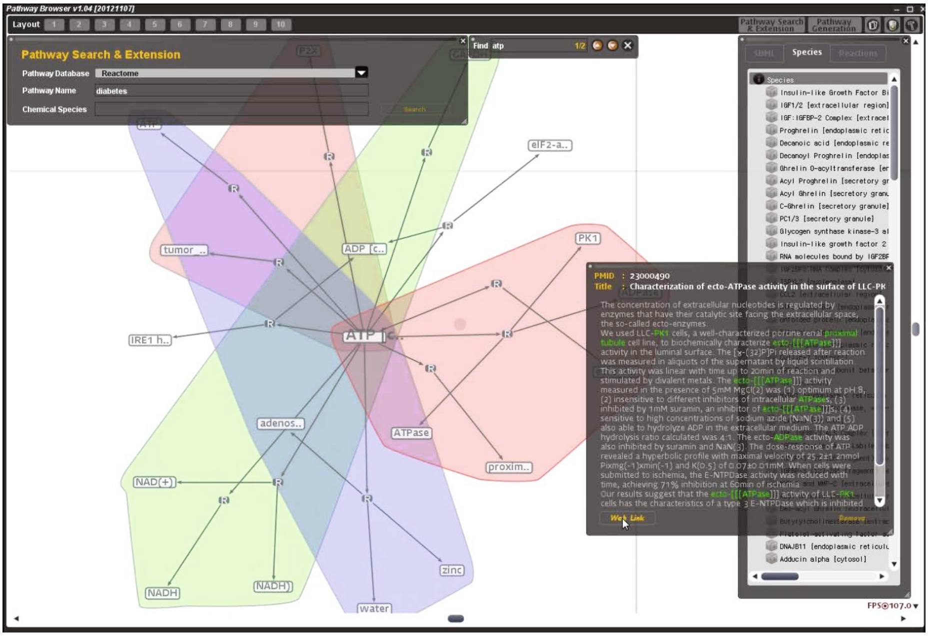

Fig. 6. Architecture of Pathway Construction

Table 1. Various Pathway Markup Languages

Pathway	Markup Language
Reactome	BioPAX, SBML
Human Cyc	BioPAX, SBML
Panther	BioPAX, SBML
Signal Link	SMBL
PharmGKB	PharmGKBML
KEGG	KGML, BioPAX
BioModels	BioPAX, SBML, CellML
HPRD	PSI-MI
DIP	PSI-MI

integration of the current pathways was complicated. The proposed approach has developed a standard format and converters from various markup languages to the standard format. Since BioPAX has more information compared with other markup languages, some information was omitted in the proposed standard format based on pathway construction.

6 Conclusion

Pathways are definitely meaningful information to analyze protein functions or protein process. The analysis can be applied to develop new treatments for such diseases. In the viewpoint of construction and maintenance of pathways, the process is labor-intensive and time consuming. The proposed approach aims to develop an automatic pathway construction and extension system. Auto generation and extension of pathways might overcome the limitations, and the performance of pathway auto-generation and auto-extension showed encouraging results. We have planned to integrate more pathway databases and to apply SBGN (Systems Biology Graphical Notation) for displaying pathways.

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Increasing Situational Awareness of Indoor Emergency Simulation Using Multilayered Ontology-Based Floor Plan Representation

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Abstract. Indoor emergency is a challenging research domain. It has to deal with dynamic situations, unexpected consequence of incidents, many entities involved such as human and building elements. Emergency simulation cannot avoid these various and dynamic information. This research proposes a multilayer of ontology-based floor plan representation in order to describe how the simulation goes with these complexities. Our approach uses ontology to model a floor plan into various perspectives e.g., *AccessibilityPerspective*, *ControllingPerspective*. Each perspective is used to support different purposes. For example, *AccessibilityPerspective* is used for way finding and navigation. These perspectives are represented by multilayer of graphs, one perspective per one graph. The research objective is to increase users' situational awareness in the indoor emergency simulation. The are two main advantages in this model. First is a capability to handle dynamic situations and consequences of emergency using ontology and inference rules. Second is the use of multilayered graph-based representation in describing the floor plan's situation in various perspectives and overcoming information overload. With these advantages, users can notice how the simulation goes, what and where have been changed in a glance.

Keywords: Multilayered floor plan representation, ontology based modeling, emergency situation.

1 Introduction

Indoor emergency is a complicated research domain. There are many changes and unexpected consequences caused by emergency incidents. This research domain also has to consider about relationship between components in various perspectives. For example, *AccessibilityPerspective*: elevator L can let ones from the first floor to access the second floor, *PowerControllingPerspective*: room R provides the electricity to the west area of the building. When an emergency happened, let follow the previous examples, room R may get some damage and

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 39–45, 2013.

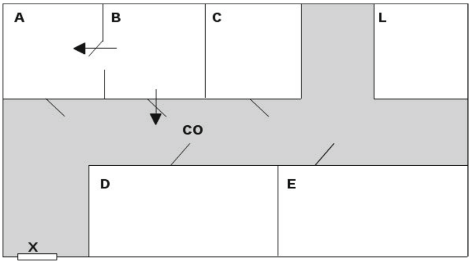


Fig. 1. An example of floor plan that consists of rooms (A, B, C, D, and E), an elevator (L), an exit (X) and a corridor (CO). Room B is a power control room that supplies electricity to the whole floor. This room is locked. It requires a key to access.

cannot provide electricity to the building anymore. Consequently, elevator L which located at the west area of the building cannot work properly. Finally, elevator L cannot be used to access to other floors. For such scenario, indoor emergency is quite complex and some relationship may be not very obvious to notice. Consequences of the incident are dynamically changes and not easy to handle. This paper propose a floor plan representation that can handle these dynamic challenges in various perspectives. We design our approach from the simulation monitoring point of view. Its objective is to increase the situational awareness [5] of indoor emergency simulation. However, since the representation have to handle information from multiple perspectives. There are many researches tried to represent a floor plan from the same purpose. Nevertheless, they seem to face problem of information overload when they had to deal with many perspectives. This paper proposes an approach to represent a floor plan in multilayer of graph, one perspective per one graph.

2 Related Works

There are series of studies indicate that the average person spends around 90% of their time indoor [1], [4]. Therefore, it is important to investigate the indoor space for our better daily life. From the navigation perspective, indoor space and outdoor space have similarities and differences [8]. For example, they share common concepts of *Passage*, *Portal* and *Barrier*. On the other hand, distances and angles play the key role for outdoor space but not much for indoor space. In indoor space, the topology plays a more prominent role. For example, connectivity becomes more important than direction. Moreover, indoor space is a kind of isolated space. We can neglect some uncontrollable factors, such as weather, in this space. However, it is still complex enough to be an interesting research domain. For example, the indoor landmarks are generally local ones because corners or wall can block our vision. Furthermore, some of them can be moved easily.

Many floor plan representation approaches have been proposed. A floor plan can be modeled in various approaches — graph-based, grid-based, 2D or 3D spatial space, ontology — to serve with different purposes e.g., navigation, tracking, simulation, visualization [3]. To represent an indoor space in multi perspectives, Bigraph is proposed by [7]. Bigraph is a visualization that combine two semantic graphs named *Place graph* and *Link graph* together. Place graph is a graph representing floor plan structure. Link graph is a special graph representing other relationship concepts between nodes in the graph. For example, representing the Internet connection between rooms in the building, representing an agent A_1 is using a computer C_1. For another example, Becker T. also proposed a multilayered space model for indoor navigation purpose [2]. The model mainly illustrated the combination of topological layer and sensor layer for navigation and positioning purposes, respectively. It required special edges, *joint-state edges*, to describe relationship of nodes between layers e.g., room A is under the range of sensor S. However, similar to Bigraph's issue, even those models can represent multiple perspectives of indoor floor plan, all perspectives are depeiceted in a single visualization planar. To handle multiple perspectives, those models are easily to reach information overload problem. For example, to represent the network connection between rooms in a building and topological accessibility between those rooms at once. In such case, instead of the representation enhances the floor plan visualization, it may become too hard to understand. Moreover, those approaches were not designed to handle consequences of dynamic situation.

3 Methodology

Our research wants to make the floor plan visualization simpler regarding to handle a floor plan representation in multiple perspectives. We propose an approach that using ontology to capture a floor plan concepts in various perspectives and represent them with multilayer of graph. The ontology is not used only to capture the floor plan's concepts, but also be used to handle dynamic situation due to the changes or consequences in indoor emergency domain.

For understanding more clearly, we describe our model with a sample scenario of indoor emergency. We use this scenario and others to evaluate our proposed model.

3.1 Scenario

Fig. 1 represents a floor plan structure. A, B, C, D and E are rooms in the building. B is assigned as a power control room which provide electricity to the whole building. Moreover, this room is locked from outside, to enter the room requires a key. L is an elevator which requires electricity to be in operation. X is an exit door and CO is a corridor. The emergency scenario is described as followed: "When an unexpected situation happens, a power control B cannot provide the electricity to appliances nor places." Based on this incidents information, what we should get from our model? Since the power is failure, the elevator L cannot operate to any purpose. Consequently, It should be classified as an obstacle element for escape purpose. The room B could be labeled as a *DangerousPlace* because it got damaged till out of function. Its neighboring rooms, *A* and *C*, are also defined as *WatchOutPlace* since they have some risk by being the rooms next door to room *B*.

3.2 Ontology

The core part of our ontology is depicted in Fig.2. Some part of them share the common components with OntoNav [6], however, our approach do not cosider only "Navigation" purpose. We consider on virious perspectives such as *AccessibilityPerspective*, *NeighborPerspective* and *ControllingPerspective.* Their descriptions are shown as followed:

- **AccessibilityPerspective** considers about how the *StructureComponents* e.g., Room, Corridor possibly connect. The distance between components does not matter. For example, in Fig.1, room *B* and *C* are next to each other. However, they cannot access to each other because there is no door linking between them.
- **NeighborhoodPerspective** considers in the component's location, not for the connectivity. For example, In Fig.1, There is only one direct connection between room *A* and room *B*. However, all rooms, *A*, *B* and *C*, are considered as neighborhood because they are close to each other in structure. In this perspective, it is possible to have neighboring link even there is no accessibility relationship.
- **ControllingPerspective** mainly considers in the element controlling e.g., electricity, water. This is an important information. Many consequences will be happened up to this perspective.

3.3 Reasoning and Inference Rules

To handle consequences of incident, we use inference rules to deal with dynamic information. For example, an Incident I is happened. It causes a consequence C_1. Then this C_1 also triggers a new rule and causes another new consequence C_2 happends. As mentioned scenario in Section 3.1, a power control room B has an incident e.g., fire. This incident causes room B as a dangerous place. Since room B is a power control room that supplies electricity to other places and alliances in the floor, including the elevator L. This matter causes the elevator L becomes an inoperating place. Finally, the elevator L is classified as *InaccessiblePlace.* In other words, our model can show how *PowerControllingPerspective* causes consequences on *AccessibilityPerspective.* Some sample rules are showed in the following equations.

$$Place(?X) \cap hasProperty(?X, DANGEROUS) \rightarrow DangerousPlace(?X) \quad (1)$$

$$DangerousPlace(?X) \cap hasPowerSupply(?X, ?Y) \cap RequireElectricity(?Y) \rightarrow Inoperating(?Y) \quad (2)$$

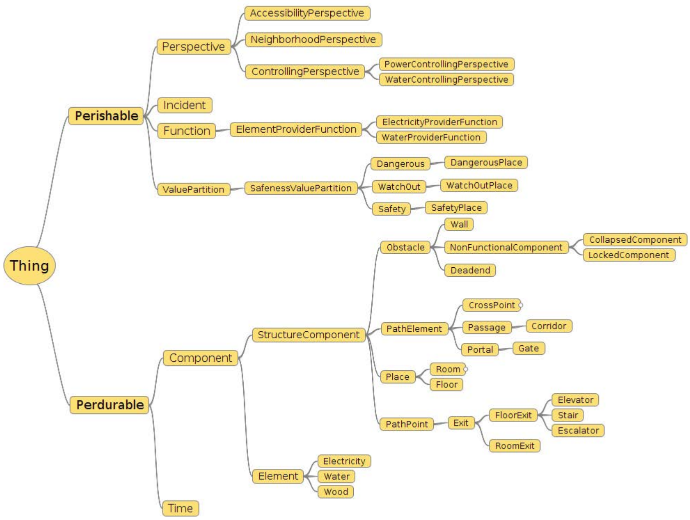


Fig. 2. Example of ontology design describing a floor plan

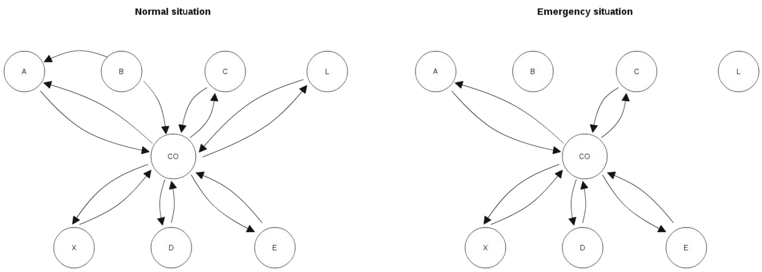
$$Inoperating(?X) \cap Place(?X) \rightarrow Inaccessible(?X) \quad (3)$$

3.4 Graph-Based Representation

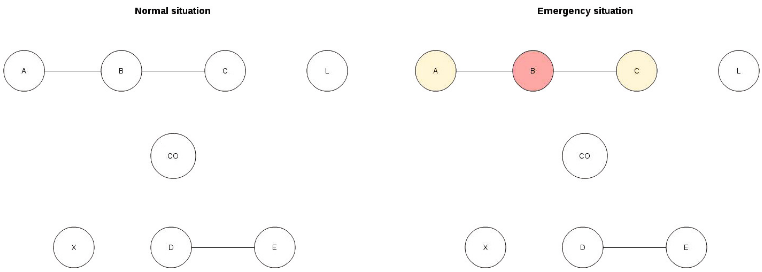
To represent each perspective with a graph, we query classes having association with properties that related to the interested perspective. For example, to represent a graph of *NeighboringPerspective*, the system queries *hasNeighobr(?X, ?Y)* to ontology. This querying retrieves a list of node X and Y that have property *hasNeighbor*. Then the system draw a graph of *NeighboringPerspective* based on the result list as showed in Fig.3b. In order to handle dynamic in emergency situation, once the inference rules produce some changes, the drawing graph module is activated.

4 Discussion and Future Work

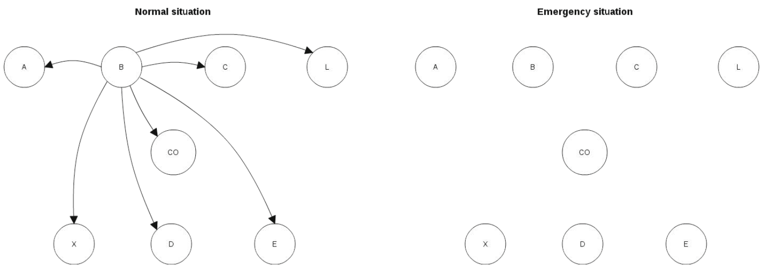
This work proposes a multilayer of ontology-based floor plan representation for supporting ontology-based indoor emergency simulation. Ontology is used to capture concepts of a floor plan in various perspectives and to link relationship among them. Perspectives are represented by multilayer of graphs. Its objectives are to increase users' situational awareness and to describe how the simualtion goes with the incident scenarios. From the scenario given in the previous section, our research shows two advantages — capability of handling dynamic-situation using ontology and inference rules, and the use of multilayered graph-based representation to lessen the information overload issue. For the future work, we



(a) Accessibility layer in normal and emergency situation.



(b) Neighboring layer in normal and emergency situation.



(c) Power control layer in normal and emergency situation.

Fig. 3. Representation graphs of various perspectives based on the given scenario and the floor plan in Fig.1. The left column images represent a normal situation. The right column images represent an emergency situation that an incident happened in the room *B*. The red and orange nodes in (b) represent *DangerousPlace* and *WatchOutPlace*, respectively.

plan to adopt this research idea with a more complicated scenario simulation. For example, to add human ontology to the scenario and explore how the dynamic environment affect the human behavior. However, this research still has some limitation. Since this representation focus on topological perspective e.g., accessibility, connectivity than geometrical perspective e.g., distance, direction. It might not be so convenient to the very-end-users.

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Development of Dual Tactor Capability for a Soldier Multisensory Navigation and Communication System

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Abstract. Development of new multisensory Soldier display systems requires context-driven evaluation of technology by expert users to assure generalizability to operations. The capture of Soldier performance demands is particularly challenging in this regard, as many factors converge to impact performance in actual usage. In this paper, we describe new capabilities for tactile communications that include an authoring system, use of android-driven displays for control and map-based information, and engineering tactors with differing salient characteristics. This allows development of a dual-tactor display that affords a larger variety of tactile patterns for communications, or TActions. These innovations are integrated in a prototype system. We used the system to present navigational signals to combat-experienced soldiers to guide development of tactile principles and the system itself. Feedback was positive for the concept, operational relevance, and for ease of interpretation.

Keywords: Tactile displays, Haptic displays, Soldier navigation, Soldier performance, Multisensory displays, Intuitive displays, Salience.

1 Introduction

Multisensory tactile display systems for military performance have demonstrated their potential for performance and tactical advantage across a number of applications. Experiments and demonstrations have been conducted across a wide range of settings, from laboratory tasks to high-fidelity simulations and real-world environments [1]. Operators of these various tactile systems have successfully perceived and interpreted vibrotactile cues even in adverse, demanding, and distracting situations. The improvements in performance are explained by two theory-based schools of thought: alleviation of sensory overload [2] and/or alleviation of cognitive deliberation [1]. In related research, it has been suggested that tactile events may be processed preattentively - tactile information is processed preferentially by the nervous system under conditions of divided attention [3]. This preferential processing may also account for the enhanced performance.

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 46–55, 2013.

The US Army Research Laboratory, Human Research and Engineering Directorate (ARL/HRED) conducted experiments with systems using tactile displays for Soldier navigation and communication. First, task analytic investigations identified key situations in which Soldiers are visually overloaded, such as missions requiring land navigation [4]. Several HRED studies were then conducted within the context of soldier land navigation, to investigate effects of tactile cues in context [5]. The studies demonstrated that Soldiers could detect not only single alerts but also patterns of multiple tactors to represent different messages. It is particularly promising that the soldiers could perceive these patterns during strenuous movements [6]. Three additional HRED experiments demonstrated the efficacy and suitability of a torso-mounted tactile belt for Soldier navigation [7]. Given this series of results from land navigation studies, it is evident that tactile navigation displays can be used in strenuous outdoor environments and can outperform visual displays under conditions of high cognitive and visual workload. In addition, Soldier feedback (e.g., after-action reviews, comments, and structured rating scales) was very positive, indicating core advantages of the system was that it was "hands-free, eyes-free, and mind-free."

The experiments described above establish the potential of tactile systems for supporting Soldier performance while easing workload and gaining high user acceptance. At the same time, Soldiers have provided many suggestions for device design before a system can be practically used in combat. Specifically, the device must be made to be lightweight, comfortable, rugged, and easily maintained. The device must enable reliable communication among Soldiers. Currently, Soldiers use visual hand signals to communicate and coordinate movements and target detection. Tactile systems can build upon these techniques, by enabling commanders to easily and covertly signal Soldiers regarding alerts or movements. This would build upon battlefield visualization techniques now common to command and control, by enabling the commanders to quickly relate critical communications as to where to go or where to shoot. In this way, distributed tactile communications could enable dynamic battle maneuvers with covert and intuitively understood signals that can be understood in high-noise, high-stress, and/or low-visibility contexts.

While considering soldier's recommendations, HRED researchers have also recognized the need for the development of tactile systems that can enable further applied research on multisensory performance issues relevant to soldier performance. These systems should provide the means by which task performance can be easily assessed, with capabilities that can track communications, time-stamp performance events, and track GPS-enabled assessment of navigation time and accuracy. This paper describes the development of one such system developed by Engineering Acoustics Inc. (EAI), to illustrate the advantage to Soldier performance in mission context, while offering a testbed for research. The resulting capabilities should generalize to many other navigation contexts: military, government, first-responder, and commercial (e.g., hiking, hunting, tourist) applications.

2 Tactile Salience

One of the general problems in all sensory perception is information overload, but humans are adept at using selective attention to quickly prioritize large amounts of information and thus give their attention to that which is the most important [2]. Historically, tactile stimuli and patterns have been described using dimensions such as the frequency, intensity, force, rhythm, location and duration of the signal [8,9]. However, these definitions and their associated thresholds are of little value in determining the effectiveness of tactile systems because they do not account for user and application specific environmental factors. For example, one cannot consider the salience of a tactile cue or message construct by signal properties alone, without consideration of physical task demands and external noise.

One of the factors that influences prioritization of sensory information by humans is Salience. Salience is the property of a stimulus that allows it to stand out and be noticed. Salience is widely used in describing visual system performance but typically has not been applied to the tactile modality. Salience models potentially can describe how attention is focused onto particular elements in complex scenes, based on both endogenous properties of the object (bottom-up saliency) as well as cognitive processes (top-down) [10]. Therefore salience allows us to potentially compare tactile symbology in a multimodal environment. A conceptual model framework for salience is described in Figure 1.

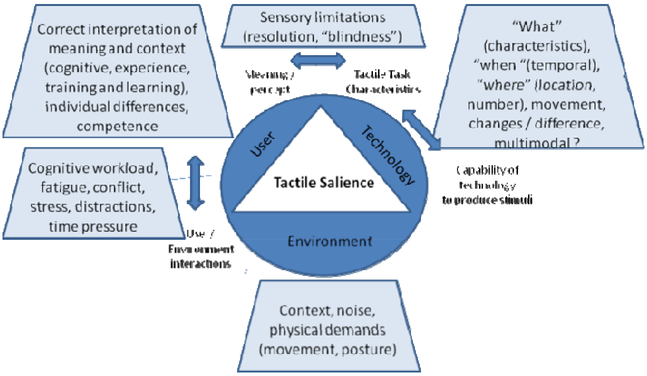


Fig. 1. Model for tactile salience. Tactile salience is situational depending on the user, environment, technology and tactile parameters.

Tactile salience depends on the user, the technology, and the environment. To be salient for diverse users, tactile display technology should provide a wide range of recognizable touch characteristics, and do so in a small lightweight, efficient system that is not limited by the mounting or usage. Features such the abrupt onset (or changes) in stimuli and high frequency (200-300 Hz) tone burst vibrations are known to be naturally salient. Touch is also arranged somatotopically (i.e., point to point correspondence of body areas to the nervous system), leading to an intuitive mapping of direction and spatial constructs [11] on the surface of the body. There are also well known sensory processing limitations that limit tactile discrimination [12]. Further external factors such as environmental noise, and human factors such as individual differences, training and experience, emotional reactivity, cognitive resources and even posture all have an effect on salience.

Tactile salience is complex and situation-dependent. Thus, predictions and principles must consider and articulate the critical situational factors that interact to effect performance with tactile systems. Design and testing of tactile array systems must replicate the intended environment and user characteristics while measuring salience. A cognitive task analysis should preface development of any system, to provide developers with information about the nature and type of information processing and environmental demands the system users are likely to encounter. In this case, the users were soldiers and therefore, the first step was to identify the mission tasks that would most benefit from a multisensory tactile approach. Consideration of mission and task context then informs tactile display requirements (e.g., tactile display must be easily perceived when performing combat maneuvers). Measurement of tactile salience may be measured through direct task performance (e.g., response times, accuracy, etc.) and also subjective reporting (e.g., confidence scales).

2.1 Dual Tactor Capability

Engineering Acoustics, Inc. (EAI) has a long history of tactile system development for many applications (including situation awareness support for aircraft pilots [13]). Currently, EAI is developing the ATAC (Active Tactile Array Cueing) Navigation Communication (NavCom) system. This system for soldiers has focused on combining two different types of tactors (C-2 or C-3 (operating at 250 Hz) and EMR) with varying characteristics, to provide a system that enables intuitive communications as well as direction information. In addition, the C-2 tactor was optimized for higher-frequency tactile signals that are easily and quickly perceived, even during strenuous movements [6]. The C3 is a smaller, lighter, and more covert version of the C-2. The EMR is a new motor-based design with an operating frequency range of 60-250 Hz. This design is able to produce a wide range of perceivable tactile features ranging from a strong "alert" to a "soft" pressure pulse or "nudge". Therefore we have designed the EMR to be capable of producing substantial peak displacements of up to 1.2 mm p-p (as measured against a phantom with the mechanical impedance of skin). In contrast, the C-2 or C-3 would typically only be driven to peak displacements of about 0.5 mm p-p owing to the relatively high PC channel displacement sensitivity. Figure 2 shows the EAI tactor types.

Fig. 2. The EAI C-2, C-3 and EMR vibrotactor transducers (left to right respectively)

The simplest informational requirements for soldiers completing a navigation task are the direction to and distance from the waypoint, and this information can be presented to them on a torso-worn tactor array. Directional information is naturally mapped to corresponding sectors on the torso, and studies [14] have shown that an array of 8 tactors in a single row around the body, is sufficient for accurate navigation (e.g., more tactors would not result in higher precision). Therefore the two tactors types are mounted in two rows within a dual flexible belt, each sector comprising an array with a C-2 (or C-3) and an EMR.

2.2 ATAC NavCom

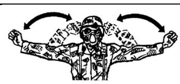
Figure 3 shows a block diagram for the ATAC NavCom system. The system comprises visual display hardware (e.g., a smartphone), EAI tactor controller and dual belt array, a COTS (Commercial off the shelf) GPS / compass sensor interfaced directly to the tactor controller and software components. Wireless task management and recording (using a cloud based database) are also provided for mission management and data collection.

Fig. 3. Block diagram for the proposed ATAC-NavCom system

Our experimental focus is on determining the effectiveness and salience of multiple tactors and tactile patterns, or TActions [15], for critical communications. Thus the NavCom system and the research it enables are expected to support the core critical demands for Soldiers – to move, to shoot, and to communicate.

The TActions were developed as easily recognizable (salient) tactile representations of the standard hand and arm "command" signals, shown in table 1.

Table 1. Arm and Hand Signals and Corresponding Tactile Signal Patterns. The illustrations are from US Army Field Manual 21-60.

Arm / Hand Signal	Tactile Pattern	Visual Pattern
Halt	Four tactors simultaneously actuated on the sides of the body	
Rally	Sequenced activation of all tactors creating a circular motion around the body	
Move Out	Sequenced back-to-front activation of tactors creating movement from each side of the body which converges in the front	
Nuclear Biological Chemical (NBC) threat	Sequenced activation on both sides simultaneously creating three distinct impulses on the sides of the body	
Take Cover	Simultaneous activation of 4 tactors (two on each side) followed by a sequenced activation of a series of tactors to indicate movement	
Attention, Prepare	Sequenced activation of four tactors in the front, emulating side to side movement	

3 Some Preliminary Findings

Several combat-experienced soldiers used the ATAC NavCom system for performance trials and provided feedback on perception and interpretation of direction and command cues, the ease of use, and issues regarding operational relevance and use. The participants were eight Soldiers from the 150th ARS (Army Reconnaissance Squadron) West Virginia Army National Guard, all of whom had combat experience (at least one tour in Iraq). Their military occupational specialty (MOS) was 19D, associated with armored vehicles, such as the Bradley, Abrams, and Stryker vehicles. All had combat dismounted experience as well (e.g., urban patrols). All of the Soldiers were male, ranging in age from 23 to 40 years. Height ranged from 60 (1st percentile) to 77 (99th percentile) inches, indicating a range of body size. Their total years in the military ranged from 3 to 21, and rank ranged from E4 (SPC Specialist or CPL Corporal) to E6 (Staff Sergeant). An additional soldier from Fort Benning with equivalent experience also participated. The experience level of the soldiers was critical for their feedback with regard to operational use.

Single cues. Each soldier was introduced to the system and was trained on the components and concept of use. Single-tactor location cues on the body were identified by *o'clock* positions, which are familiar concepts to all soldiers. After a brief introduction to each tactor position, soldiers demonstrated their proficiency through a training set of direction cues. In the absence of visual cues, they were to respond to a set of tactile single direction cues, presented with the EMR tactors, as well as with the C-2 tactors. The EMR tactors were as effective (mean = 0.5 errors) as the C-2 tactors (mean = 0.62 errors) for direction cues. Examination of the error types show no particular pattern. The total number of errors were low and most of the participants had none. Most of the errors were accounted for by two participants.

Commands. Each soldier was then trained on six hand and arm signal patterns used during land navigation (Attention, Move out, Take cover, NBC, Rally, Halt) presented with the tactors belt. The trainer introduced two signals, had the soldier identify each correctly, then would add another signal, until the soldier could correctly identify each of the three (twice). This protocol continued, adding a signal to the group until the soldier could correctly identify all six. They were trained to proficiency in less than five minutes. Some of these patterns were modified versions of those developed in previous efforts [16]. The Soldiers then responded to a set of 24 counterbalanced tactile cue patterns, presented through C-2 tactors. All Soldiers identified all patterns correctly.

Commands and Directions. After completion of training on the set of tactile Commands, each soldier learned a set of counterbalanced cues that mixed tactile commands (C-2 tactors) with tactile direction cues (EMR tactors). Most of the soldiers performed with a perfect score. One soldier confused "Take Cover" with "Move Out", and a second soldier confused direction 6 with direction 4_5.

Robot commands. Because soldiers sometimes use robotic assets during land navigation, a notional set of six commands were developed for communication from a robot to the operator (Look at display, Wheels are spinning, Road is rocky, Steep incline left, Steep incline right). Soldiers were introduced to the tactile patterns representing these messages, as before, and practiced until they were proficient, taking less than five minutes to do so. They were then presented with a randomized counterbalanced set to identify. All soldiers identified all cues correctly.

Soldier comments. Soldiers provided comments and ratings (using a 7 point semantic differential scale in which 1 = very difficult, very ineffective, strongly disagree to 7 = Very easy, very effective, strongly agree; etc.) with regard to system features and operational relevance. Table 2 provides mean Likert ratings of effectiveness. All ratings were positive, ranging from a mean of 4.75 for daytime route navigation to a mean of 5.88 for night operations. Soldiers agreement was high for positive statements (e.g., it was easy to feel) and low for negative statements (e.g., the signal was annoying).

Table 2. Mean degree of agreement (7pt Likert scale) to statements regarding system features

Degree of agreement with:	Mean rating
It was easy to feel each tactile signal	6.38
The tactile signal should be stronger	3.25
The tactile signal was annoying	2.62
It was easy to understand what each signal meant	5.25
I was very certain what each signal meant	5.63
I recognized each signal immediately	5.50
The tactile cues are a good means of silent communication	5.63
The tactile cues are too noisy for regular patrols	3.25
The tactile cues are too noisy for covert missions	4.50
The tactile cues are a good substitute when radios cannot be used	5.63
The tactile cues help keep my attention on my surroundings	5.00
The tactile cues can be a useful way for soldiers to communicate	5.88

Soldier comments. Soldiers offered many comments with regard to the advantages and issues dealing with the tactile interface. Soldiers particularly valued the hands-free aspect, as it allows them to keep weapons in hand. They also commented on the usefulness of the tactile cues for situations where visibility is limited, such as night operations and combat (e.g., smoke). In such situations it was felt that the tactile direction alerts could be easily perceived and intuitively followed, allowing the soldier to maintain attention on their environment and sources of threat. Soldiers listed several missions where this capability would be useful, such as urban operations, dismount patrol, room clearing, area and zone reconnaissance, and guard patrol.

Soldiers also pointed out issues that may be relevant in certain missions. They noted the noise, while tolerable for normal operations, may not be acceptable for covert missions. In this evaluation, the tactile signal strength was high, and this is associated with a slight buzzing noise. The signal can be reduced, when appropriate. In addition, caution should be taken with regard to the number of commands, to keep TActions to critical communications that are very easily distinguished. These issues are being addressed through the TAction authoring system and adjustability of the system to lower the volume of the signals. A critical aspect to such a soldier system is to afford the soldier the ability to adjust signal patterns and strength, or make new signals to best accommodate the mission at hand.

4 Discussion

Multiple experiments and demonstrations have supported the theory-based predictions regarding advantages of haptic and tactile cues to support performance in high-workload situations, particularly multi-tasked situations with high demands for focal visual attention. Task analysis models identified that Soldiers have very high demands for visual attention, particularly when they are moving or shooting. Subsequent experiments proved the value of tactile systems to support their navigation and communication. As tactile displays are increasingly used for communication of more complex and multiple concepts, it will become evident that tactile and multisensory systems in general must be designed for salience (i.e. rapid and easy comprehension). This paper described efforts underway toward the goal of effective support of Soldier performance, and the development of a system that can also be used for grounded research (i.e. high generalizability to military operations) in multisensory perception and comprehension. With regard to operational use, flexibility is critical. While default settings can be engineered to be effective in most situations, Soldiers need and want the ability to create their own signals and adjust the "volume", to best accommodate specific mission goals and requirements.

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The Study of Surveillance around the Ship II

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Abstract. The main causes of maritime accidents are derived from insufficient surveillance. In a narrow channel, there are a lot of opportunities which a ship encounters other ships. Therefore, we need to pay attention to steer ships sufficiently. In this situation, the ship watchers convey accurate information to the ship pilots, then, ship pilots have to provide direction of steering precisely. It is not easy to determine the surrounding circumstances and give instructions to steer the ship in a short time. Therefore, it is needed that the system to support surveillances which shorten the time of transmitting the circumstances to the ship pilots. In this study, we will generate the 3D surveillance model of acquired images with surveillance cameras which set up for all directions on the ship and radar images, and we propose a new method to display information around a ship. In this experiment, we have tested our proposed system with actual images at "Shioji-maru".

Keywords: information system, 3D surveillance model, lookout, RADAR, panoramic image.

1 Introduction

According to statistics provided by The Japan Coast Guard of accidents at sea in 2011, around 800 to 900 collision accidents at sea per year happened in the past five years. Looking at kinds of accidents, collision accidents consist of 30% of all accidents. The main causes are anthropogenic factors, among them, it is indicated that collision accidents caused by insufficient surveillance especially have happened many times. However, there are many opportunities to encounter other ships in congestion of marine areas and navigators always need to grasp their surroundings. It is not easy for them to keep confirming their surroundings in the middle of doing various operations in the ship there are a tiny number of navigators. From the present situation like this, the following two things are important. One is to support navigators to grasp their surroundings more quickly to prevent them from occurring their accidents. The second is to record the situation surrounding ships clearly in order to examine and analyze their accidents.

In this study, we obtain visual information of surrounding ships as images captured from all circumferences by cameras. Then, we make 3D surveillance model from the

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 56–65, 2013.

images and radar images, we propose the method which images of arbitrary eye direction are displayed depending on the situation. At the same time, we also aim for establishing systems which are able to record and providing useful information to analyze accidents.

2 Related Research

As the study to support surveillances, it is reported the study to support visual recognition [1-2] and the study about integrated display of navigation information. These studies propose the method of supporting surveillances by using visual information about the direction of bow, however, they do not propose the method that integrate omnidirectional images included backward ship and marine navigation information of other ships, they do not also propose the method that display them on one screen at a time.

In recent years, that is part of the reason that damaging to other ships by suspicious ships has become a problem, it is in great need for keeping an eye on our backward ships. Easily having a wide-angle view that not only images from specific direction but also omnidirectional images in the ship is especially effective in an early detection of suspicious ships and a course decision of burdened ships.

Furthermore, in relating to a way of acquiring images, the method [3] that displays images around our ships by using a fish-eye lens has been proposed. Shooting by using a fish-eye lens makes it possible to shoot omnidirectional images by one camera, therefore, it has some advantages to be easily-controlled and to be inexpensive. However, it is constitutionally difficult to identify small targets like small ships because the resolution acquired images decrease. In this paper, we acquired images by using "camera array system" that some cameras are connected to acquire high-resolution images.

3 Information around Ships

Information around ships consists of visual information, radar information, and direction information of other ships, weather information, AIS information and so on. In these information, navigators actually attach overriding importance to visual information when they keep guard. In case they cannot interpret the situation visually when they keep guard, they complement information, for example, distance to the target, by matching the visual contact to radar information. In doing so, they grasp the situation. In addition to that, moving direction and moving velocity of other ships are estimated by measuring relative directional change which when we watch other ships from our ship. Then, a 3D surveillance model (Fig.1) obtains visual information that we think important during our surveillance as real-time omnidirectional images, makes it possible to streamline surveillances by integrated display of radar information and direction information.

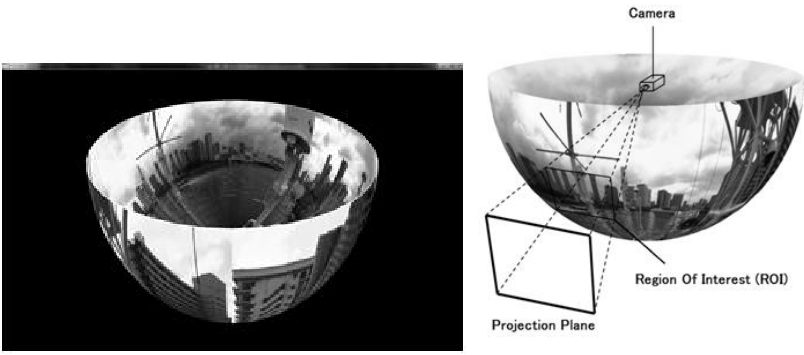

Fig. 1. 3D Surveillance Model

4 3D Surveillance Model

We describe an outline and a rough progression of 3D surveillance model, then we make a proposal about a way of surveillance images, a way of connected surveillance images, a way of making radar images, a way of information integration and a way of information display.

First, we define a hemisphere shape in 3D space of Computer Graphic (CG). We make images integrated radar information and direction information in surrounding images as texture. Then, a model done texture mapping [4] to the hemisphere shape is defined as 3D surveillance model. Setting observer's eyes (a camera) in place into the hemisphere shape, users move interactive eye direction with a mouse and so on toward the hemisphere shape. So, they can see (display) arbitrary directional texture (omnidirectional images, radar echo, and amplitude) that put on the hemisphere shape. We show our outline drawing in Fig.1. In this study, we utilize the method of texture mapping for preserving integrated information images in order to display integrated information of omnidirectional images etc. and to analysis as we describe later. Texture mapping might happen to some problems that a delay of display and display of resolution, however, it does not have a big influence on its behavior, if it is used the resolution of this study.

4.1 Creating Image Capture Device

We make connected surveillance images from some images obtained by an image getting equipment (Fig.2) created in this study. We also obtain radar images by using an image distributor from an equipment of radar images display. Radar echo are only extracted from obtained radar images, radar images expressed disk-shaped by Cartesian coordinates conversion are converted into belt-like ones. We produce information integration images (texture images) from these two images. The texture images are superimposed based on location information and direction of bow taken various images, then, echo images are not done projection transformation because of an execution of high-speed processing. By doing this, radar echo are accurately not projected into omnidirectional images, though, the texture images are fully able to convey navigators to the state they should check from radar echo pixels and a direction.

We project these images produced into hemisphere of 3D space in succession, and we display images of arbitrary direction by using a display method we propose in this study.

Fig. 2. Capture Device

4.2 Omnidirectional Image

We consider what we connect images obtained from five cameras and shape omnidirectional visual information into one image as a connected surveillance image. In our shooting equipment set up a disk of cameras, even if we take a picture with a camera and with next to a camera like including the same target, the dimensions of the target in the shooting image are different.

In this study, we consider an amendment by using cylindrical projection. We produce connected images (Fig.3). The way is what we once project images shot by five cameras into cylindrical side, and sticks the images together on the cylindrical side.

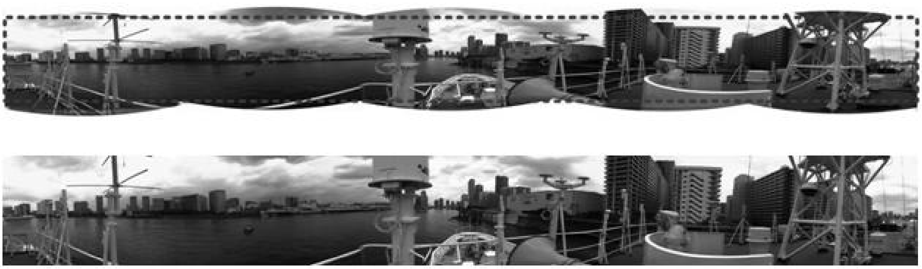

Fig. 3. The omnidirectional image

4.3 Radar Image

We produce radar images expanded to a horizon area from images (Fig.4) obtained by using the image distributor through the equipment of radar images display. At first, we clip radar echo display area of obtained radar images, and extract only radar echo by using arbitrary threshold from brightness value information. We consider the radar echo display area as polar coordinates, convert it to Cartesian coordinates (Fig.5).

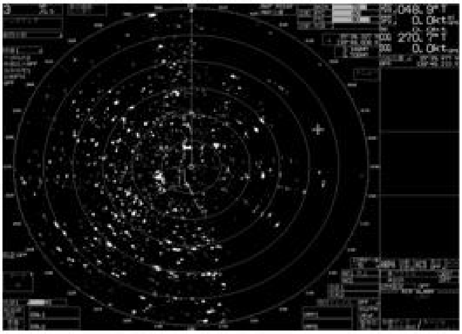

Fig. 4. Captured Radar Image

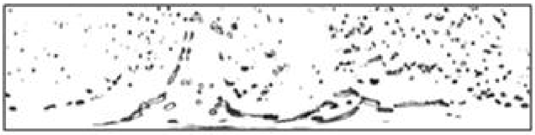

Fig. 5. Radar Echo

4.4 Integrated Information

In the 3-D surveillance model, we integrate radar information and direction information with images obtained around our ship, and we display it. In the integration of radar information, we incorporate the connected surveillance images we made with images we extracted radar echo (Fig.6 circles are a part of echo). On this occasion, we match position of the target on radar information to position of the target on visual information, positioning each horizontal line on their images.

Fig. 6. Texture including Radar Echo

4.5 Textures Mapping

Original images were thought to be due to record distribution of lights under lighting condition. If a light source becomes fixed, each point of color becomes a function that has only reflectivity coefficient, this coefficient remains unchanged. Therefore, even if observing point changes, each point of color on object surface does not change. This distribution of reflectivity coefficient is called texture in the field of CG. In general, by mapping original images as textures on 3D object surface and curved surface, we can produce images of arbitrary observing points.

In this study, we map textures generated by this method on the hemisphere. In this method, images become unusual shape because textures were compressed and mapped near the poles. Though textures mapped near the poles on the hemisphere do not accurate shape, these are images enough to confirm. The pole in this method, in short, the bottom of the hemisphere is our less important ship or our camera table. We express as moving images through we map texture images generated by integrated processing information in series.

4.6 Information Visualization Method

We propose the way of information display of 3D surveillance model. With respect to a coordinate system, a vertical upwardness in 3D virtual space is plus direction of Z-axis, Y-axis of horizontal XY flat-surface is a depth. There are two display methods we propose, one is a parallel projection from Z-axis direction, the other is a parallel projection to XY flat-surface and vertical flat-surface.

The parallel projection from Z-axis is a method that texture mapped on hemispherical virtual space is projected parallel from Z-axis's upper direction to XY flat-surface and to parallel projection plane. In the projection plane, it is projected what is combined omnidirectional images with radar images. In this way, we make it possible to check on the surrounding situation in a short period of time without moving the visual direction to our circuits and the radar screen during our surveillance due to be able to match radar information as the same time as looking at omnidirectional images.

A parallel projection to XY plane and vertical plane is a method of displaying projection plane by a parallel projection of texture mapped on the hemisphere toward XY plane and vertical projection plane.

It reflects what we scrap parts of area from omnidirectional images in projection plane. We can change our visual line to arbitrary direction, because we can convert the direction of projection plane and the size of clipping area by mouse operation. Especially, we think it proves to be useful in surveillances that we can grasp small ships etc. approaching from backward of our ship even if we are on a bridge.

It is possible to grasp the surrounding situation easily by switching these two display methods depending on the situation. The Parallel projection of Z-axis direction, however, is not shown accurate shape because an icon is compressed toward a center of images. It is not also easy to measure the distance to a target depending on a visual position and a visual direction in a parallel projection to XY plane and vertical plane.

We deal with this as displaying distance information.

5 Experiment

5.1 Experiment Content

In this study, we set up shooting equipment on the deck of training ship "Shioji-maru" of Tokyo University of Marine Science and Technology, then, we made our experiment of taking images. Our experiment was performed when we anchored "Shioji-maru" in the daytime. At the time, it was a sunny day and visibility was good. We sequentially acquired surrounding images and radar images in real time, then, we examined whether these images were displayed or not by our 3D surveillance model. We obtained images from shooting equipment in 2.0 frame/s and radar images in 0.5 frame/s. Computer system configuration diagram at our experiment is as follows (Fig.7). We produced computer programs operating on the top of our operating system Windows, looked into the semantics by outputting images at 27-inch display monitor of 1980×2080 resolution.

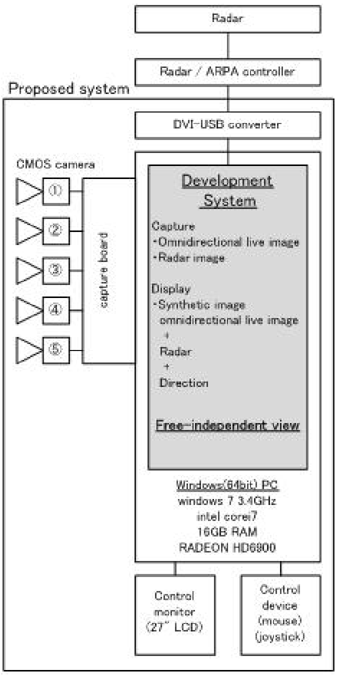

Fig. 7. System Install

5.2 Experimental Result

Fig.8 is the image that we captured displayed-contents when we experimented. We confirmed that radar images were displayed, having an overlap with shooting images and that we are able to overlook complete periphery of our ship by mouse-driven viewpoint switching. We could not confirm ships at all that displayed clearly as radar echo because our experiment environment was located in very narrow marine area when it comes to matching to radar information. Surrounding landform and buildings were displayed as radar echo on the images. On this occasion, we visually confirmed through binoculars and we checked what verification of radar echo and the direction of actual landform was completed.

Concerning a display speed, we recognized that displaying frame rate of surveillance images in the present system was 1.0 frame/s. About a record, we preserved the texture produced as JPEG images of 1frame/s (about 2.0MB per flame). Owing to this, it was possible to record without omissions with the capacity of about 2.9GB in four hours. We also checked that the texture recorded was able to display of playing by making use of this method.

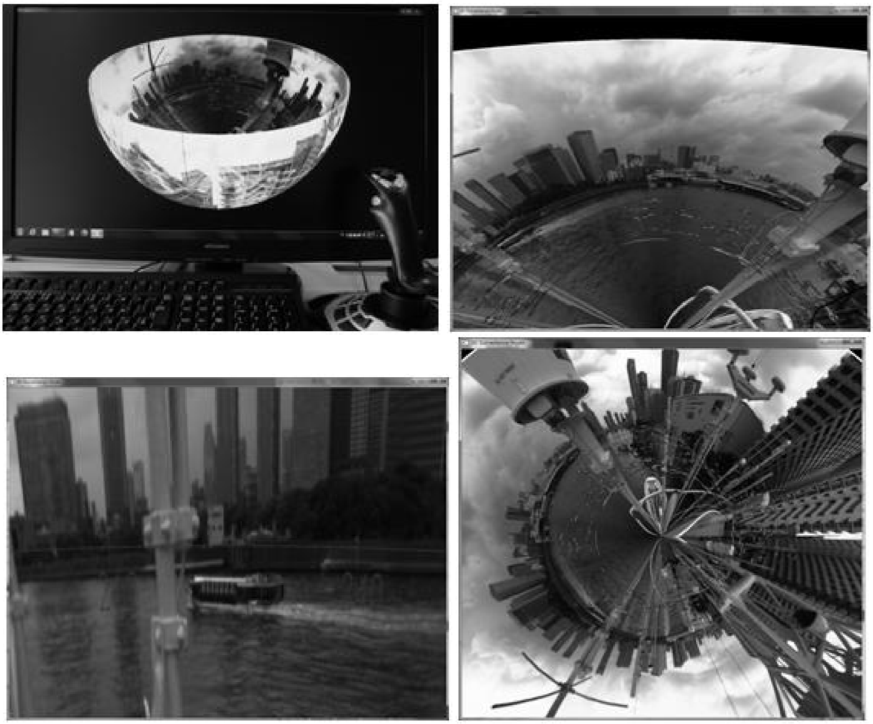

Fig. 8. Result Image

6 Discussion

Through this experiment, we confirm that it is possible to display some necessary parts in response to surrounding situations even if we are on a bridge by using two display methods we propose as the situation demands. Especially, when we check the surrounding situation, it was an efficient way to grasp our ship that we overlook around our ship by the parallel projection from Z-axis direction, then, as soon as we check other ships, we grasp directional information, we switch to the other display method and enlarge the images. At this time, if we lost other ships, we could find these easily because we can enlarge and scale down display areas.

When we displayed radar information with images, a space between targets of radar information was kept, then, we could display a positional relation in an easy-to-understand manner.

We also displayed our ship on the image any numbers of times in this experiment, circumstances surrounding which is necessary information were displayed as compressed images. We need to set up shooting equipment on higher position and confirm this movement.

In this study, we easily display integrated information of arbitrarily-visual line direction and utilize the method of texture mapping in order to preserve integrated information images which we displayed to analyze. In the texture mapping, we assume some problems such as a delay of display and low-resolution images. Although the level of resolution images we use in this study has not significant impact on this movement. Then, like Imazu's method, it is easy to change 3D visual line direction to the image projection on the hemisphere (texture mapping) than the image projection on 2D surface. Therefore, we can easily realize the display all-round at one time such as fish-eyes lens.

In the future, we consider a correspondence of hopping. We also do not take measures about swing in this study. It is reported [5] that if we use our equipment under the situation of shaking when we keep guard, recognition rate of our equipment becomes diminished. So, we need to take measures. Relation to this, we consider that we clear away swing by using swing elimination algorithm [6].

7 Conclusion

In this study, we set up the hemisphere face in the virtual space and integrated information on the hemisphere. From our experiment, we confirm that it is reasonable to support that the method of integration, the method of display and visual line switching. We also make it possible to provide useful information to analyze the situation when accidents happen by recording pictured images and radar images simultaneously. As future subjects, we will deal with taking pictures when it is rain and when it is at night, then, we will display integrated AIS date and weather date into images by cooperating with other systems.

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Developing a High-Fidelity Simulation and Training to Improve Coordination between Aerospace Specializations

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Abstract. This paper describes the various technological elements used to create and support a simulated flight operations control center for the purpose of collegiate aviation training. The simulation center also serves as a platform to research team dynamics, educational efficacy, and individual occupational stereotypes. The simulation facility relies on the harmonious integration of technologies to meet operational requirements including realism, flexibility, and capability

Keywords: aerospace, aviation, airline, operations, multi-team, training, simulation.

1 Introduction

This paper presents the theoretical background behind the development of a simulated flight operations center for training of aerospace specialties and research conducted in that center. The nature of simulation and training is discussed, including a summary of ongoing research efforts and future developments.

2 Theoretical Background

A variety of highly-trained professionals are needed to operate an airline. These include pilots, flight dispatchers, meteorologists, crew schedulers, ramp controllers, and maintenance coordinators. Airline employees in these roles must not only be proficient in their respective specializations, they must also work together in a coordinated manner. Effective teamwork is essential for optimal airline operations. This is especially true when irregular events and disruptions occur ([1], [8], [13]). Previous research suggests that newly hired aviation professionals often do not possess high levels of interpositional knowledge required for highly coordinated action [6]. Poor

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 66–75, 2013.

coordination can lead to costly flight delays, inefficiencies, and may even compromise safety. Flight delays and cancellations result in inconvenienced passengers, disruptions in business activities, and downstream operational problems for airlines. The negative economic impact resulting from airline delays and cancelations in the U.S. is estimated to exceed $31 billion annually [10]. While disruptions and mistakes cannot be eliminated entirely, more effective coordination among differing specializations of aviation professionals can reduce their frequency, duration, and impact. In order to improve interpositional understanding, decision-making, and group situational awareness, we utilize a series of high-fidelity simulations that incorporate both routine and non-routine work situations. We also engage teams in after-action reviews to further enhance the educational benefits of the simulations. Theory and research on group processes, group/team performance, and multi-team systems provide perspectives from which to view and improve the coordination needed to maintain optimal airline performance.

As effective teamwork is important for optimal levels of group performance, multi-person simulations that reinforce essential task and teamwork functions are considered to be an effective approach to team training ([4], [11], [12]). Despite the fact that training on complex tasks facilitates transfer, most of the training literature tends to focus on relatively simple, routine tasks rather than complex, dynamic tasks requiring adaptation [5].

3 Simulation and Technology

3.1 Participants

Participants are senior-level Aviation Science students enrolled in a culminating capstone course. Students are assigned to 10-member teams according to their aviation specialization. The following degree specializations are represented in each team: professional pilot, flight dispatch, maintenance management, aerospace administration, and aviation technology. All participants have completed extensive coursework in his or her respective specialization, but may lack knowledge of, and experience working with, other specializations.

3.2 Setting

Simulated flight operations are conducted in a multi-room lab facility called the Flight Operations Center Unified Simulation (FOCUS) lab. This facility includes the main flight operations control center, adjacent ramp tower, pseudo-pilot room, CRJ flight simulator, and an observation and control room. To the greatest extent possible, the creators of the lab sought to replicate key elements typically found in airline operations centers.

The FOCUS lab has multiple workstations, each with unique responsibilities. Many of the world's largest airlines operations centers are comprised of twenty or more separate departments of differing roles. For the purposes of the FOCUS lab, eight key roles were identified that students could serve based on their chosen educational specializations. These roles are: *Flight Operations Coordinator, Meteorology, Crew Scheduling, Aircraft Loading, Schedule and Flight Tracking, Maintenance Control, Ramp Tower, and Flight Crew.*

In the FOCUS lab, students are positioned in an elongated round-table configuration. This encourages face-to-face communication, though headset and text communications are also available. Six large screen monitors are wall-mounted, three behind each long side of the tables so that each side displays pertinent information. This includes the flight schedule, a radar view of the flights in the air, and a weather map. All of this information is updated in real time as the simulation progresses. Finally, each workstation is equipped with a computer and dual monitors to accommodate all information relevant to that position.

Observation Room. In addition to the student roles listed above, several faculty and student observers monitor team performance and interact with the positions as needed to facilitate the delivery of scenarios, realistic events, consequences, and other external communication. These observers constantly oversee the condition of flight statuses, decision-making, routine tasks, and response to unusual circumstances. They also play external roles within the company such as upper level management, gate agents, and base mechanics, for example. This interaction contributes significantly to the realism and depth of the simulation.

The **ramp control tower** is in an adjacent room and simulates the operation of one of the airline's hub airports (Nashville). The ramp control specialist directs arriving and departing flights to appropriate taxiways and gates and provides notification when a flight is ready for pushback. This room contains three wall-mounted large screen monitors providing panoramic real-time views of the gates, runways, and taxiways. Another display shows a radar view of flights preparing for landing and takeoff, and a computer allows the operator to direct the planes to gates and taxiways. The ramp control specialist can communicate with the flight operations coordinator via headset or text.

The **pseudo-pilot room** consists of a workstation where flights within the service area are 'flown' by an operator. The pseudo pilot monitors and controls multiple flights and communicates with flight operations and simulation controllers as necessary. This location consists of a single computer station for controlling flights and another for communications and information-sharing utilities.

3.3 Student Roles

- The *Flight Operations Coordinator* (FOC) has the most central role and has final decision making authority for the airline's operations. In order to make effective decisions, this person utilizes information from all other simulation participants. The FOC collects information from the other positions to lead the team, set operational strategies and policy, and manage disruptions as they arise.
- The *Meteorologist* reviews current and forecasted weather conditions for all flights prior to departure. He/she shares the responsibility of ensuring weather conditions are acceptable for each flight to safely and legally depart. The meteorologist also monitors weather trends and unfavorable weather conditions to relay pertinent

information to flight crews, dispatchers, or the flight operations coordinator as needed.

- *Crew Schedulers* manage flight crews and monitor their duty times, currencies, and qualifications. They may reposition or reassign line and reserve pilots and their routes as needed.
- *Aircraft Loading* personnel review passenger and cargo manifests, allocate fuel, and ensure the proper weight and balance of each aircraft prior to departure.
- S*chedule and Flight Managers* monitor the status and progress of flights while they are enroute to their destinations. They also make data entries into a schedule management system that other team members rely on for accurate flight status information.
- *Maintenance Controllers* manage the aircraft fleet by assigning aircraft to flight routes, coordinating scheduled and unscheduled repair work with maintenance bases, and even help flight crews in-flight if necessary.
- *Ramp Tower Operators* manage the gate and ramp activity at large airline hubs. They facilitate the smooth flow of inbound and outbound traffic, especially during a period of high traffic volume, commonly referred to as a 'push'. Tower Operators maximize resource utilization, especially gates, ground personnel and related equipment.
- *Flight Crews* fly simulated flights along predetermined flight routes. In the simulation, pilots act either as 'Pseudo Pilots' or an actual flight crew, piloting a full-size professional flight simulator.

3.4 Implementation

To the greatest extent possible, the creators of the FOCUS lab sought to replicate the look, feel, and utility of a typical operations center. As these centers rely heavily on technology to accomplish organizational tasks, so did the FOCUS lab. However, since many of the technological tools used by airlines were not commercially available, and since a training facility of this type had never been created elsewhere, a number of existing technological tools had to be adapted and merged to accomplish the intended project goals. The following sections describe the hardware and software components used in the lab.

3.5 Hardware Components

As discussed, there are six main positions in the main operations center. Each station is outfitted with desktop computer workstations. Each workstation drives dual 19-inch LCD monitors, effectively increasing desktop space and allowing simultaneous viewing of multiple information and communication windows. The monitors are positioned to their lowest vertical orientation to allow for direct visual contact with other team members and other information sources in the room. Stations are also outfitted with monaural headsets for voice communication. There are six 55-inch high definition (1920x1080) displays mounted to opposing walls in the control center. The displays are arranged in two banks of three: three displays on each wall. They display common-use information including the flight status board, aircraft tracking, and weather radar. The displays are driven by a bank of three desktop class PCs and are controlled by central positions. For example, the Schedule and Flight Managers manipulate data on the flight status board that is displayed for others' reference.

The display computers do not directly connect to the displays themselves. Since the distance from the displays to their driving computers exceeded the maximum recommend cable length for DVI-D signals (10m), DVI signal extenders were used. The signal extenders accept DVI signals at the source unit and send reprocessed signals over a CAT6 STP cable to a receiving unit, which outputs the original signal. The DVI extenders were sourced from Smart-AVI™ Inc. and include model numbers DVX-RX200 and DVX-TX200 for the receiver and transmitter units respectively.

The displays also feature the ability to switch to any source computer output dynamically. This allows students to arrange pertinent information on any of the six screens. This required the use of a DVI matrix switch. Before signals are sent to DVI extender units, seven DVI outputs from display computers connect to input banks on the matrix switch. The DVI extender units are then connected to the output banks of the matrix switch, which connect to the corresponding displays. The 8x8 matrix switch is sourced from Smart-AVI™ Inc, model DVR8X8S.

A major component of the FOCUS lab is the custom-built NexSim suite. The NexSim suite is a contained subsystem of computers, support equipment, and software that simulate flights traveling throughout the preprogrammed service area. The NexSim Suite is intended for air traffic control training, but for the purposes of flight operations, was altered by the vendor, Computer Sciences Corporation (CSC), to meet our specific requirements. The installed NexSim suite includes six desktop class computers, and nine rack mounted computers, each with unique roles. For example, four computers generate the virtual airport environment, while others host external communication data or display airport environment and control screens. The NexSim suite also incorporates a proprietary voice communication protocol and is controlled by LCD touch panels at each station. The ramp tower room is solely comprised of NexSim equipment and features three 47-inch displays depicting a 150-degree view of the airport environment.

The FOCUS lab also features a full-size, professional flight training device (FTD) or flight simulator. This simulator is sourced from Frasca International and replicates the flight deck of a Canadair Regional Jet (CRJ) 200 series aircraft. Student pilots act as captain and first officer crews in the simulator and perform functions exactly like those in a real jet aircraft. The Frasca CRJ200 simulator and the NexSim suite exhibit the unique ability to electronically interface to share aircraft position data, despite the fact that the CRJ simulator is physically located 5 miles away from campus at the local municipal airport. This is accomplished with the use of two client computers, one each for NexSim and Frasca, and one server computer that manages and hosts the information exchange. Both the CRJ simulator and the NexSim suite publish and read decoded, nonproprietary data across a private network up to 60 times per second. This is accomplished using a sophisticated VPN architecture, developed by the two respective simulation vendors. This benefits both companies, because the connection doesn't require access to protected software code. The connection therefore allows

CRJ pilots to integrate seamlessly with the other computerized flights in the operations center. It appears both as a radar target and a photorealistic aircraft in the ramp tower. The connection also allows students in the operations center to have direct VoIP communication to pilots in the CRJ simulator.

3.6 Software Components

The FOCUS lab requires a number of software components to support the various jobs performed by students. Software in the lab falls into three main categories: simulation, communication, and information management.

Simulation Software primarily consists of the NexSim application, which is a proprietary program designed for air traffic control purposes. NexSim also employs Microsoft ESP—a professional flight simulation package used to create the visualizations of the airport environment. Users interact with the NexSim application to launch scenarios, monitor and control flights, and collect flight status information. FOCUS lab administrators also have the ability to customize scenarios to their needs. Weather conditions, flight volume, destinations, routes, altitudes, aircraft types and airports are a few examples of user-definable variables within NexSim script files. Two strings of software code used in the script file are listed below as an example:

```
00:00 SPAWN LTN1227 CRJ7/G 0 KMEM P1549 D1549 0 130
KMEM..JKS..BNA NEXT=LTN2227 PARK=C12
00:00 NEXT LTN2227 CRJ7/G 0 BNA P0015 D0015 0 150
BNA..SYI..RMG..KATL NEXT=LTN3227 PARK=C12
```

These lines are read by the NexSim application and tell the computers how flights should behave. The first line instructs the system to spawn a CRJ700 with flight number "LTN1227" 00:00 (MM:SS) after scenario launch. Its origin is Memphis (KMEM) at a proposed departure time of 15:49UTC. It will cruise at 13,000ft to Nashville (BNA) via the JKS VOR. Upon arrival, the flight will park at gate C12, and become flight LTN2227. The next line dictates instructions for flight 2227 and so on.

Communication software was needed to allow students the ability to communicate using voice, text, or by sharing screens. A number of potential solutions were considered, Skype was ultimately selected because it was scalable and flexible enough for our changing needs. Skype is installed on all computers other than those running NexSim. Each workstation has a unique username that allow for quick access. The usernames follow a naming protocol that list the station name followed by ".focus.mtsu". The application's flexibility allows for single and multi-party voice and text communications, facilitating improved problem solving within teams. Observation and control staff also use Skype to play external roles in the simulation and monitor team interactions.

Aside from the voice and text capability Skype offers, a web-based application, 'join.me' is used extensively. Join.me shares the host computers screen(s) with others who have a unique 9-digit access code. All computer workstations in the flight operations room run join.me in the background. Observers join these sessions and can monitor the work being done at each station. Screens can be viewed by on mobile devices as well. This technology allows the lab to quickly and easily expand as needed without the need for expensive duplication hardware.

Information Management Software represents one of the largest components of the FOCUS lab. All stations in the main flight operations control room use some form of information management software. Because each position has unique roles and responsibilities, each position utilizes an equally unique software module.

First, the maintenance control position uses web-based software from Talon Systems called Resource Maintenance System (RMS). This system allows maintenance controllers to monitor scheduled maintenance events, aircraft parts inventories, manage required legal maintenance logs, and keep maintenance records. Since it is web-based, observers can embed repair scenarios and monitor changes from any location.

The Flight Operations Coordinator, Meteorologist, Crew Scheduler, Aircraft Loading Manager, and Flight Status Manager all utilize 'modules' contained in a single network-shared Microsoft Excel file. This file has been in development for over two years, and contains twelve worksheets. Students interact with five of these worksheets or 'modules' to perform their jobs, while the remaining worksheets are used to store large quantities of backstory data pertaining to the airline. For example, two worksheets are used to house and interpret raw weather data periodically collected from the National Weather Service online database. Others are used to calculate aircraft performance, flight route times, financial performance, passenger lists, and crew schedules. The five student-use modules collect, return, and interpret data from the support modules.

The master Excel file is approximately 100MB in size, due to the large quantities of background data it contains. The modules also make extensive use of Visual Basic macros and conditional formatting. The file has over two hundred unique macros and approximately 1,500 conditional formatting instructions. We also extensively use stacked logic functions and cell referencing. Macros, conditional formatting, and complex formulas allow for a degree of automation to be built in to each module. Stacked IF, OR, and AND functions, working with cell referencing, creates powerful student-use tools that allow them to manage, enter, and interpret data quickly.

We elected to write our own software for two reasons. First, commercial airline operations software from vendors like Sabre® are extremely expensive, customized for each airline, and consequently unavailable. Second, although these professional systems are highly detailed and capable, we needed software that was quick to learn, easy to use, and yet still offered similar capabilities. This requirement stemmed from curriculum limitations that only gave students 10 hours of exposure in the FOCUS lab. Creating our own modules also gave us the flexibility to make changes and improvements as project goals evolved. This is difficult to do with licensed software.

4 Execution

Students participate in the FOCUS lab as employees of a fictional regional airline called "Universal E-Lines". The airline serves 14 airports from its two hubs and is comprised of a fleet of 30 regional jet aircraft. During each simulation session, approximately 70 flight events (takeoffs and landings) occur. Much of the activity involves routine handling of flight operations. However, unexpected disruptions (also known as irregular operations) occur and further increase the need for communication, information transfer, coordinated action, and adaptation. When this happens, critical decisions must be made to mitigate disruptions while maintaining a safe, efficient, and on-time operation. Often, student operators are required to draw upon their specific knowledge and that of others to quickly consider the likelihood, scope, and execution of dozens of possible strategies, while constantly being mindful of the ever-changing conditions of the airline, as well as possible downstream implications of a proposed decision. Students also feel added pressure to make decisions quickly, and often without complete or accurate information.

Student exposure to the lab consists of a series of simulation components: orientation, task-specific training, initial simulation, initial after-action review, second simulation, a second after-action review, a third simulation, and a third after action review.

Orientation. A 45-minute presentation and discussion provides a description of the lab and the various work roles. At the conclusion of the orientation, participants are informed of their team assignments and given a schedule of training activities.

Task Specific Training. During this 45-minute to one-hour session, teams are taken into the lab and provided with individual instruction, demonstration, and an opportunity to practice his or her tasks. The purpose of this session ensures that each participant develops an understanding of his or her role, responsibilities and the technical knowledge to do the job.

Simulation Sessions. Simulations are designed to recreate operational tasks and situations that real airlines address on a daily basis. Upon students' arrival, flights are already enroute to their scheduled destinations. Students assess the status of the airline and assume control of its operation. Simulations typically last for 2.5 to 3 hours, allowing consequences of poor decisions to fully develop while reducing the possibility of fatigue and complacency. Simulation proctoring involves monitoring student performance and communications, as well as interacting as needed to facilitate simulation events and triggering problems. Observers assess the condition of the airline and its variables and deliver triggers that take advantage of an opportune situation to maximize the potential for disruption and thus the need for teamwork and coordination. Team response is recorded and then discussed to see if further action is needed, especially since disruptions usually cause a ripple effect of resulting problems. Teams are faced with triggers of increasing complexity and frequency as they gain experience from each session.

After-Action Reviews. Following each simulation, participants individually complete a form detailing successful and unsuccessful events and their contributing factors.

Teams then participate in a facilitated follow-up session to discuss the positive and negative events. Then the behaviors that contributed to these events are discussed and teams develop methods to anticipate and reduce negative behaviors and reinforce positive behaviors. This session typically lasts one hour and is considered a significant contribution to the educational value of the simulation experience.

5 Future Directions

The initial position training is being developed into on online module that students would complete prior to entering the simulation for initial training. Initial training will then focus on procedural rather than declarative knowledge and move more quickly into team interaction.

Additional performance measures are also in the process of development. While many subjective measures are in place, the only current objective measure is delay time, creating pressure on participants to sacrifice other important variables in order to minimize delay time. The addition of passenger disruption, cargo delivery delays, safety considerations and fuel consumption measures are all under consideration.

Further research is planned to examine the effects of training on emergent cognitive states and to examine the relations of processes and cognitive states to team performance.

Additional equipment and expanded software capabilities are needed. Objectives benefitting from additional technology include improved team observation and monitoring, increased interactivity, Excel module user interface improvements, real-time excel data sharing, expanded NexSim capabilities, procedural improvements and an expanded scenario library. Improvements in these areas will greatly enhance simulation realism and training goals.

6 Conclusion

Merging multiple technological tools has allowed the MTSU Aerospace Department to create a unique training facility that immerses students from varying aviation disciplines in a realistic airline operations control center. Students also gain a greater understanding of their interdependence, decision-making skill set, and communication patterns. Additionally, the FOCUS lab acts a research platform to faculty from both Aerospace and Psychology departments for the purpose of gaining a better understanding of team dynamics and the effects of occupational stereotypes. Since students put their specialized knowledge to work while they run their positions, faculty can also qualitatively evaluate possible knowledge holes in the training curriculum. Although some technical limitations linger, the lab has proven its effectiveness and relevance to educators, students, and employers alike.

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Training Air Traffic Controller Trust in Automation within a NextGen Environment

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Abstract. To meet the increasing demands for air travel in the U.S., the NextGen program is introducing new automation tools and changing the way that operators in the National Airspace System perform their jobs. Air traffic controllers in NextGen will rely on these automation tools to successfully manage aircraft in their sector. It is important that these operators be sufficiently trained, and that they trust the automation tools. Yet, no research has attempted to directly train individuals to trust automation. We report on a training study that was designed to train novice air traffic controllers to trust the automated tools of NextGen in a radar internship course. We then evaluate how the students' trust in automation influenced their performance, workload, and situation awareness.

Keywords: trust in automation, NextGen, training, workload, situation awareness.

1 Introduction

The National Air Space (NAS) is introducing new automation technologies and operating concepts to accommodate a projected increase in air traffic density in the future [1]. This revolutionary system, known as the Next Generation Airspace Transportation System (NextGen), completely changes the way the NAS functions. The roles of air traffic controllers (ATCos) and pilots are likely to change with the introduction of new procedures and automation tools. For example, digital communication, Data Comm, reduces the amount of voice communications and allows flight plan changes to be transmitted and executed without the need for manual inputs. Some automated tools are being designed to assist with conflict detection and resolution (CD&R), either at the request of ATCo, or autonomously. These tools are being developed to

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 76–84, 2013.

decrease ATCo cognitive workload, a known bottleneck in the current NAS, and to ensure safe and efficient air travel.

The success of these automation tools will depend on a number of factors. One factor is how these tools will impact operator situation awareness (SA). SA is the operators understanding of a dynamic work environment. Low SA has been shown to play a role in pilot and ATCo operational errors [3]. Although automating tasks previously performed by humans reduces workload, it can also reduce operator situation awareness due to operators being out of the "loop" [2]. Other factors that will affect the success of NextGen include training and the attitudes of trained operators toward these new tools. The success of NextGen tools will depend on both novice and expert operators being trained to manage traffic with these tools, and in the near term, to manage traffic using current day and future NextGen procedures.

1.1 Trust in Automation

Several operator factors mitigate the benefits of automation. Factors such as operator acceptance and trust of the new tools and procedures, operator compliance with appropriate use of new rules, and operator complacency, or over-reliance on automation can limit the benefits of automation in the workplace [4]. In this paper we focus on the impact of trust in automation and whether trust in automation can be trained.

Although there is no general agreement on the definition of human-machine trust, many researchers define it with reference to interpersonal (human-human) trust. Rotter defines interpersonal trust as an expectancy that an individual has about whether they can rely on another's actions or words [5]. Boon and Holmes define trust as the extent to which confident predictions can be made about another's motives [6]. Muir suggests that human-machine trust does not differ largely from human-human trust [8]. Muir describes human-machine trust as a person's expectation that the machine will be proficient at what it is designed to do [7]. Accordingly, reliability is one factor affecting trust. Rovira and Parasuraman evaluated ATCo performance with automated conflict detection tools and found conflict detection was faster and more accurate when the tool was 100% reliable [8]. However, imperfect automation degraded conflict detection performance, by increasing the number of visual scans on the radar display. Moreover, ATCos felt more confident ignoring the automation when its reliability was less than 100%. Performance was also poorer when the automation tools missed conflicts as opposed to when the automation tools alerted false conflicts.

1.2 Training NextGen Automation Tools

In addition to trust, the success of NextGen will depend on adequate operator training, both for expert ATCos, with extensive training and experience with current day manual air traffic management and for novice ATCos, who have little air traffic management experience. Recent research on training methods for NextGen focus on best training methods for mixed-equipage airspaces because in near-term NextGen, ATCos must be able to manage traffic with manual tools concurrently with NextGen automated decision aids. Kiken et al., for example, measured training of experienced ATCos on NextGen tools [9]. Retired ATCos were trained on a new sector using manual skills. After they were able to manage the traffic in the sector without any losses of separation (LOS), they were trained to manage the same sector using two potential NextGen tools: trial planner with conflict probes and integrated Data Comm. Although training on managing the sector with NexGen tools took roughly the same amount of time as training with manual skills, ATCos' performance was more efficient when they managed all AC using manual tools compared to when either some or all of the AC were equipped with NextGen tools.

Additional research on novice ATCos investigated whether NextGen tools should be learned before manual skills (part-whole task method) or learned concurrently with manual skills (whole task method) [10]. Student ATCos were tested for their proficiency at managing traffic in scenarios when all AC were NextGen equipped, no AC were NextGen equipped, or a mixture of the two. The results showed that more efficient traffic management occurs after practice with the whole task, especially when the student ATCos were lower in proficiency.

1.3 Training Trust in Automation

As described above, the success of NextGen automated tools will depend on several factors including the operator's trust in the efficacy of the tools and training methods tailored to the experience of the operators. In the present investigation, we investigated whether trust in automation could be trained in student ATCos completing a radar internship course consisting of two lab periods. One lab group was provided with trust training and feedback; the other lab was not. The effect of this training was assessed at the midterm and end of the course.

2 Method

2.1 Participants

Fifteen students (2 female & 13 male) from Mount San Antonio College, an FAA CTI Institution, served as participants in this study. They participated in a 16-week radar simulation internship held at the Center for Human Factors in Advanced Aeronautics Technologies (CHAAT).

2.2 Materials

Participants were trained and tested on scenarios using the Multi Aircraft Control System (MACS) software [11], which simulated Indianapolis Center (ZID-91). ZID-91 traffic flows included overflights, arrivals to, and departures from Louisville International Airport. When the lab was in session, the students served as pseudopilots for each other and during the experiment confederate researchers were used as pseudopilots.

2.3 NextGen Tools

This course trained students on three NextGen tools: a trial planner, conflict probes, and integrated Data Comm. Conflict probes are background functions of the system that use an algorithm to detect conflicts, or potential losses of separation (LOS), within a certain amount of time. The trial planner is used to change an aircraft route within the dynamic environment by clicking and dragging on the route, which can be uploaded to the aircraft with integrated Data Comm. Data Comm is a digital communication tool that allows ATCOs to digitally transmit handoffs, frequency changes, and various aircraft clearances.

2.4 Training Procedure

The radar simulation internship in CHAAT consisted of 3.25 hours of radar simulation lab training and 1.5 hours of classroom lecture each week. A retired, radar-certified ATCo taught the internship. Students were enrolled in the lecture session and one of 2 lab sessions (morning or afternoon). Students attended the lecture portion together and spent the first 8 weeks of the internship learning basic ATM techniques such as managing traffic using altitude, speed, heading changes. In addition, students were trained on how to create a structured airspace and communicate with proper phraseology. Both lab sessions were trained to use manual and NextGen tools concurrently. Each lab session received a different percentage of equipped aircraft in the training scenarios. For the first 8 weeks of the course, the morning lab session received training on scenarios with 25% equipped aircraft and the afternoon lab received training on scenarios with 75% equipped aircraft. This meant that students in the morning lab had more practice with voice and manual skills while students in the afternoon lab had more practice with NextGen tools. An experimental midterm test was administered during the eighth week of the internship. The trust training manipulation occurred after the midterm. During the last 8 weeks both classes practiced on scenarios that had 50% equipped aircraft. However, the morning class (control group) continued to receive normal training and the afternoon class (trust group) was provided feedback when they moved a “near-miss” aircraft inserted into the scenarios. Near misses were aircraft that came close to the separation minima, but would not lose separation, and therefore were not alerted by the automation tools. Movement of these aircraft suggested that the student mistrusted the automated conflict resolution tool. A final experimental test was administered at the 16-week of the internship.

2.5 Experimental Procedure

Participants completed the experimental midterm test during the 8th week and the final test during the 16th week of the internship. At the beginning of the internship, participants were administered a demographics survey. The midterm and final exams began with a 10-minute warm-up scenario prior to the experimental trials to familiarize participants with the situation awareness-probe technique used in the simulation. Following the practice scenario, participants completed four 40-minute experimental scenarios with each scenario containing 0%, 50% or 100% equipped aircraft. Situation awareness probe questions were presented to the student controllers using the Situation Awareness Present Method (SPAM) [12], beginning 4 minutes into the scenario and at 3-minute intervals afterwards. These queried the students about information such as conflicts, traffic and workload. The order of scenario presentation and probe questions were partially counterbalanced. At the end of each scenario, participants completed NASA-TLX and Situation Awareness Rating Technique (SART) questionnaires. For the final exam, the last scenario consisted of 50% equipped aircraft and a Data Comm failure that was scheduled 10 minutes into the scenario: confederate pseudopilots stopped responding to Data Comm messages. Ten minutes after the failure, participants were informed that the Data Comm tool was not operable and to use manual communication for the remainder of the scenario. At the end of the final test session, participants were verbally debriefed on their experiences in the radar course and during the midterm and final test procedures.

We evaluated the effectiveness of training by recording the number aircraft moved for near-miss conflicts at the midterm and final. For the final failure scenario, we recorded the number of Data Comm messages sent prior to and following the failure event. We also evaluated the effect of Trust Training on Workload and Situation Awareness because effective automation aids should decrease operator workload while maintaining situation awareness.

3 Results

Mixed ANOVAs were run on the variables of interest, with the within-subject factor Testing Session (Midterm vs. Final) and the between-subject factor Training Method (Trust vs. No Trust Training) for the 100% and 50% scenarios.

3.1 Trust

Number of Near Miss Equipped Aircraft Moved. The 50%-equipage scenarios contained only one near-miss event, making the possibility of finding differences between training groups extremely low. Even in this case, though, a marginally significant interaction between training class and test session was obtained, $F(1,13) = 3.55$, $p = .08$, as shown in Fig. 1. Participants in the Trust Training group on average were less likely to move one of the near-miss aircraft pair at the Final test ($M = .57$, $SEM = .17$) than at Midterm test ($M = .86$, $SEM = .16$). Participants in the No-Trust-Training group were more likely to move the aircraft pair at the Final test ($M = .88$, $SEM = .16$) than at Midterm test ($M = .75$, $SEM = .15$).

For the 100%-equipage scenario, only two near-miss events occurred. All main effects and interactions were nonsignificant, (p’s >.25), but the pattern of results was similar to the 50% scenario.

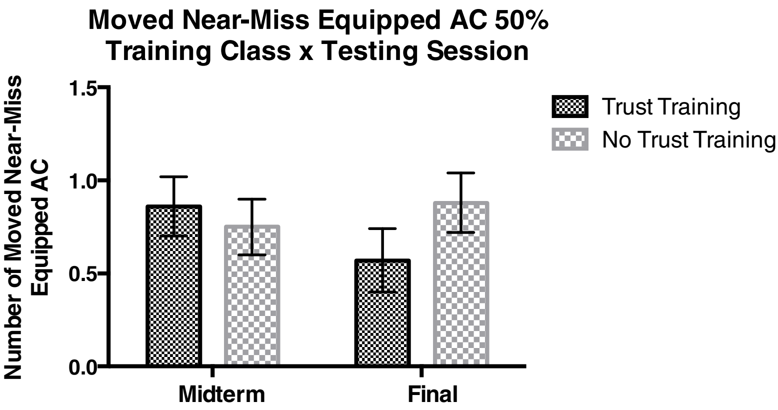

Fig. 1. Average Near-Miss equipped AC moved by each training group at the midterm and final exam for 50% equipped scenario

Number of Sent Data Comm Messages. A mixed ANOVA was run on the number of Data Comm messages sent before and after the Data Comm failure. The repeated factor was Failure Interval (10 min Before Data Comm Failure vs. 10 min after Data-Comm Failure) and the between subjects factor was Trust Training (Trust Training vs. No Trust Training). A main effect of Failure Interval was obtained, $F(1,13) = 24.7$, $p < .001$. Significantly more Data Comm messages were sent after the failure (*M* = 10.1, *SEM* = 1.2) than before the failure (*M* = 8.2, *SEM* = .78). However, the main effect of Trust Training and the interaction between Training and Failure Interval were non-significant (*p*s > .45).

3.2 Workload

NASA-TLX workload scores were analyzed with a three-factor mixed ANOVA. The within-subject factors were Equipage (50% vs. 100%) and Test Session (Midterm vs. Final), and the between-subject factor was Trust Training (Trust vs. No Trust). A marginal main effect of Equipage was found, $F(1,13) = 4.23$, $p = .06$, such that workload was lower for the 100% equipped scenario. This main effect was modified by a significant interaction between Trust Training and Equipage, $F(1, 13) = 6.15$, $p = .03$. As shown in Fig. 2, the No-Trust- Training group reported higher workload for the 100% equipped scenarios (*M* = 42.3, *SEM* = 5.7) than the Trust-Training group (*M* = 27.7, *SEM* = 6.1). For the 50% equipped scenarios, the difference between groups was minimal (No Trust: *M* = 40.9, *SEM* = 5.9; Trust: *M* = 42.9; *SEM* = 6.3).

Online workload ratings were analyzed similarly, and the interaction between Equipage and Trust Training was again significant, $F(1,13) = 6.80$, $p = .02$. Overall, the Trust Training group (*M* = 2.73, *SEM* = .38) had lower workload ratings for the 100% scenario compared to the No Trust Training group (*M* = 4.15, *SEM* = .35). For the 50%-equipped scenarios, no significant differences in workload were observed.

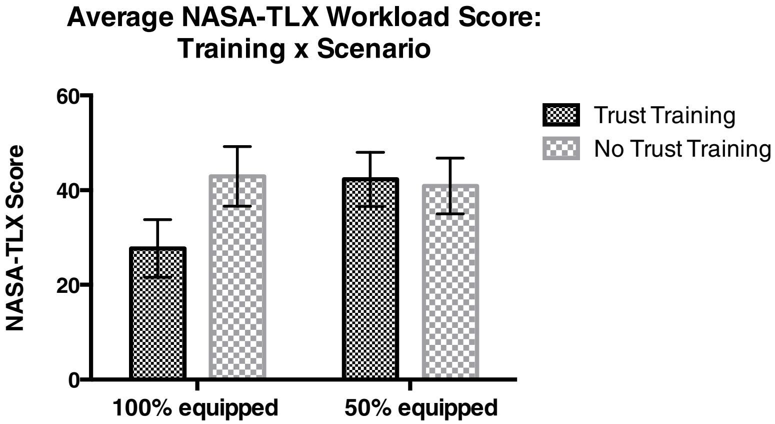

Fig. 2. Average NASA-TLX workload scores as a function of equipage for both Training groups

3.3 Situation Awareness

Mixed factorial ANOVAs were performed on overall SART scores, SPAM probe latency and SPAM probe accuracy.

SART Ratings. A significant interaction between equipage and training was again obtained, $F(1,13) = 6.08$, $p = .03$. Participants in the No Trust Training group (M = 6.71, SEM = .39) showed higher SART ratings than the participants in the Trust Training group (M = 5.52, SEM = .42) for the 100% equipped scenarios. This difference was not significant for the 50% scenarios.

SPAM. For SPAM probe latencies, significant main effects of Test Session, $F(1,13) = 5.06$, $p = .04$) and training group, $F(1,13) = 8.46$, $p = .01$) were obtained. Overall situation awareness improved from Midterm test (M = 15.1 s, SEM =.72 s) to the Final test (M =12.9 s, SEM =.71 s). Moreover, the No Trust Training group had higher awareness overall (M =12.4 s, SEM =.73 s) compared with the Trust Training group (M=15.5 s, SEM =.78 s). For SPAM probe accuracy, only a main effect of equipage was obtained, $F(1,13) = 14.9$, $p = .002$, such that participants were more accurate for 50% equipage scenarios.

4 Discussion

Our main question of interest was whether providing training on trusting automation to student ATCos would improve their trust in a NextGen tool for automated conflict detection. Two measures of trust were used: the number of times students moved “near-miss” equipped aircraft and the number of Data Comm messages sent after a Data Comm failure. Near-miss aircraft were those that came close to but did not lose separation with another aircraft. We expected the Trust-Training group to move fewer of these near misses because they would rely on the automation to alert them of actual conflicts. We also expected that the number of Data Comm messages sent following a simulated Data Comm systems error would be higher in the Trust-Training group due to the group's reliance on the technology.

Unfortunately, the numbers of near misses in our test scenarios were very small. For 100% equipage, two near misses were scheduled, and for 50% equipage only one near miss occurred. Given the low numbers of opportunities for observing training differences as well as the small sample sizes, the chance of obtaining significant differences was extremely low. Nevertheless we found a marginally significant interaction between test session and training for the 50% equipage scenario, such that more students in the No Trust group moved the near-miss aircraft than students in the Trust group. This occurred only at the final exam, which indicates a possible effect of trust training. We did not find an effect of Trust Training on the number of Data Comm message sent after the planned failure. Regardless of training, both groups sent more messages following the failure (possibly to the same aircraft).

If trust training was effective, then workload for the Trust Training group should be lower; accordingly, the Trust-Training group reported lower workload than the No-Trust Training group did, but only for the 100% equipage scenarios. Possibly, when all aircraft are equipped, the No Trust group persisted in using manual scanning skills despite the fact that the automated conflict detection and resolution tool was 100% reliable. For the 50% equipage scenarios, no differences in workload were reported. This also explains why students in the No Trust Training group reported higher situation awareness for the 100% equipage scenarios based on SART post-run rating scores. For SPAM probe latencies, the interaction was non-significant, but the main effect of training indicated that the No-Trust groups had higher awareness.

5 Conclusion

Students in the trust lab reported lower workload and lower situation awareness for 100% equipage scenarios. We also found that students in the Trust Training group tended to be less likely to move a near-miss aircraft. Note also that our trust intervention was minimal, consisting only of additional practice on NextGen tools early in the semester and feedback when a near-miss aircraft was moved in the second half of the semester. These results, although preliminary, indicate that training trust in automation needs to be researched further. These findings were based on student controllers, with little-or-no previous radar experience in air traffic control. Experienced controllers could be less affected by training trust in automation [13].

Acknowledgments. This project was supported by NASA cooperative agreement NNX09AU66A, Group 5 University Research Center: Center for Human Factors in Advanced Aeronautics Technologies (Brenda Collins, Technical Monitor).

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Augmented Reality System for Measuring and Learning Tacit Artisan Skills

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Abstract. Many traditional artworks in Japan are now facing the issue of raising successors to conserve their culture. It usually takes decades to learn artisan skills in conventional way. We propose a learning system using augmented reality technology to help transferring techniques in one of the Japanese traditional papermaking *kamisuki*. First, we measured the expert's motion and extracted tacit skills. Second we examined the relation between extracted motion and paper quality by software simulation. Finally, we developed a projection based augmented reality system that visualizes experts' tacit skills to leaners when they train papermaking. As a result, the system helped enabling learner to obtain techniques to improve the quality of paper in short time period.

Keywords: Augmented reality, Tacit knowledge, Physical skill training, Cultural heritage.

1 Introduction

Industrialization and low birthrate in Japan accelerated the declining in inheritance of many traditional arts. Conventionally, skills of traditional arts are transferred by word-of-mouth between a master and apprentices. Decades of efforts are required to learn those techniques for apprentices. Within this learning framework, only limited number of apprentices can learn the craftsmanship. This process has demanded great tolerance and made inheritances of traditional arts extremely difficult.

Recently, there have been efforts to record those artisan skills in textbook or video. We can learn the basics of traditional arts a little easier than before. However, those media can hardly transfer artisans' techniques that relates to fine control of bodies, tools, and environmental conditions. Several researches have been done on conservation of traditional craftwork skills in digital way. There is plenty of research on digital archiving of tangible cultural heritage such as paintings, craftworks and

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 85–91, 2013.

buildings [1, 2, 3]. Some researches focus on the artistic movements such as dance [4]. However, focus of these studies is on the existing art objects or artistic movements themselves, not on the artisanship to create those art objects. Saga et al. developed a unique system to transmit calligraphic skills using haptic feedback [5]. Our approach takes a similar attitude toward preservation and transmission of skills, but in a more integrated way with various sensors, taking deeper look at the tacit knowledge of experts numerically. We have created an integrated framework for the digital preservation of artisanship [6, 7]. In this paper, we explain our framework for digital archiving of craftwork skills, and show a verification experiments in which we applied the system to a Japanese traditional craftworks, *kamisuki*.

Kamisuki is a technique to craft traditional Japanese paper, washi. *Kamisuki* is starts from scooping the liquid, which is mixture of water, pulp of *kozo,* and glue, by wooden tool called *sukigeta*. Then swing *skigeta* back and forth to circulate scooped liquid over the *sukigeta* in order to spread pulp of *kozo* over *sukisu*, which is a bamboo mesh clipped inside the *sukigeta*, and accumulate it to form a piece of paper (Fig. 1). Formerly, we developed a wearable display system that provides an experience for learner from first person view of an expert [8]. This training system achieved a remarkable speed-up in learning of basic movement in *kamisuki* for beginner. As a next step, we made progress into training of paper quality improving technique.

Fig. 1. Three main movements in Japanese papermaking; scooping, swinging and draining (*from the left*)

2 Proficiency and Handcrafted Paper Quality

We measured uniformity of paper between three persons in different level. Subject A is a holder of special technique to be preserved, authorized by Ministry of Education, Culture, Sports, Science and Technology. Subject A has refined his *kamisuki* skill for 30 years. Subject B has 10 years of experience in *kamisuki*. Subject C is nearly a beginner who trained basic skill of *kamisuki* with our wearable display system [8].

In order to evaluate uniformity of paper, we cut square 10 cm on a side from the top and the bottom of a paper and compared the weights of these two pieces. If paper is made more uniform the difference will become smaller. We asked subjects to make 9 pieces of paper and measured the difference of each paper (Fig. 2).

As a result, we found that the uniformity improves in the order of subject A (30 years of experience), B (10 years of experience), and C (beginner). Higher skill leads to the high quality of papermaking.

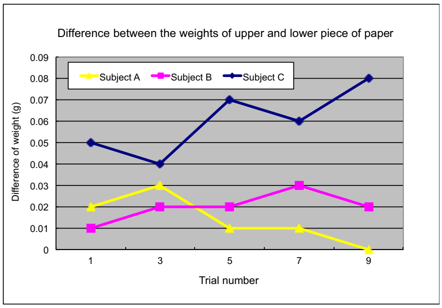

Fig. 2. Measured the difference of weight of 10-cm-square pieces cut off from top and bottom side of a paper (*left*). Results in difference of weight of each subject (*right*).

3 Analyzing Expert's Skill of Making Uniform Paper

3.1 Measuring Unobservable Difference in Motion of *Sukigeta*

A piece of paper is formed by a set of swinging movement of *sukigeta*. Therefore, difference in this movement of each subject made the difference in uniformity of paper. In order to extract the characteristics of this movement of expert (subject A), we set a laser range sensor (Hokuyo URG-04LX) over the *sukigeta* to visualize detailed movements of *sukigeta* (Fig. 3).

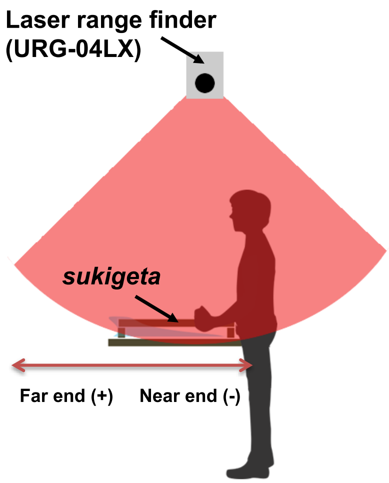

Fig. 3. Experiment setup for measuring detailed motion of *sukigeta*

3.2 Measured Difference in Motion of *Sukigeta*

We measured the movement of *sukigeta* of three subjects mentioned in chapter 2 with the system described in previous section. As a result, remarkable characteristic in motion of *sukigeta* in subject A was found. We found two techniques in manipulating *sukigeta* (Fig. 4).

Technique 1. Center of oscillation of sukigeta is shifting back and forth for three times during a swinging period of papermaking.

Technique 2. Oscillation amplitude of sukigeta is gradually gets larger during a swinging period of papermaking.

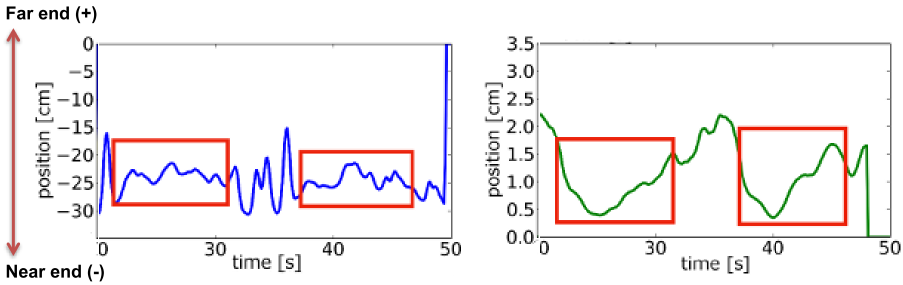

Fig. 4. Two characteristics was found in movement of subject A's *sukigeta*. Swinging period of papermaking is clipped by red rectangles. Shift of center of oscillation (*left*), and width of oscillation amplitude (*right*).

3.3 Relation between Measured Difference and Paper Quality

In order to verify whether two techniques we found in expert's manipulation of *sukigeta* leads to uniformity of crafted paper, we examined the relation between movement of *sukigeta* and accumulation of pulp.

We simulated how fragment of pulp piled up onto a virtual *sukigeta* (Fig. 5). NVIDIA PhysX was used for physical simulation. Each subjects' movements of *sukigeta*, measured by laser range sensor was reflected to the virtual *sukigeta*. Particles located on a virtual *sukigeta* are abstract model of pulp. White particles are illustrating drifting pulp; red particles are precipitated pulp on virtual *sukigeta*.

The results of simulations showed that motion data of subjects A was the best to precipitate particles uniformly onto a virtual *sukigeta*. Subject B's motion data made better uniformity of precipitating than subject C. During this precipitation process, technique 1 (shifting of center of oscillation) contributes in moving groups of particles back and forth; technique 2 (increasing oscillation amplitude of *sukigeta*) contributes in stirring particles to spread drifting particles to avoid precipitating in narrow area as the density of drifting particles get sparse.

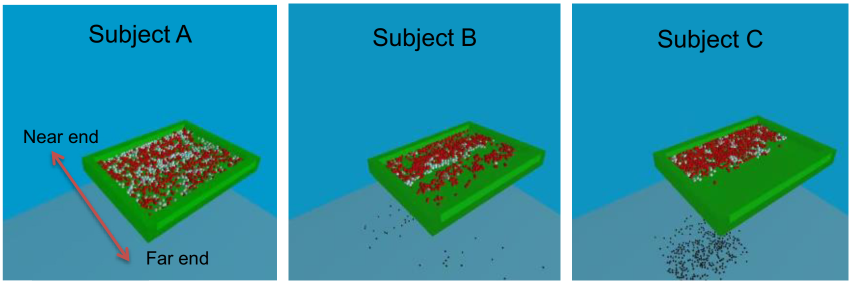

Fig. 5. Physical simulation of precipitating pulp on *sukigeta*

4 Projection Based Augmented Reality Skill Learning System

We developed projection based augmented reality display to coach aforementioned two techniques during the papermaking process. Subject A's motion of *sukigeta* is indicated by augmented reality presentation superimposed onto *sukigeta* (Fig. 6).

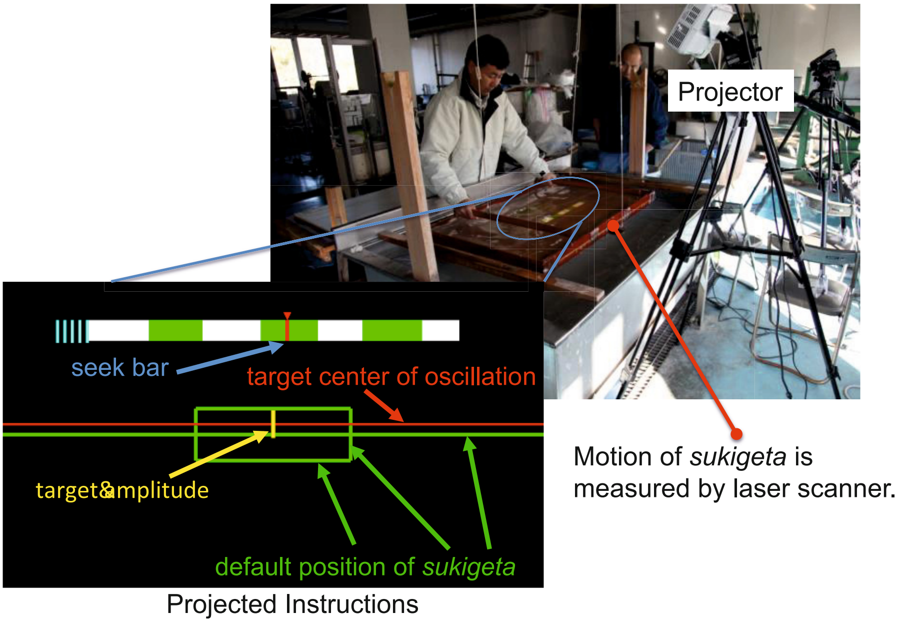

Fig. 6. Augmented reality based learning system. Light green areas in seek bar indicate swinging period during papermaking. Learner must scoop liquid from a sink during white areas in seek bar. Red horizontal line indicates target center of oscillation and length of yellow vertical line indicates the width of oscillation amplitude.

5 Learning Experiment and Result

We conducted training experiment by using developed projection based augmented reality skill learning system to four learners. In addition to aforementioned subject B and C, subject D and E who have same skill level as subject C are added in this experiment. Since the motion of technique 1 varies rapidly, besides presenting raw motion data of subject A, we designed presenting quantized motion data as an indication of target center of oscillation data. In quantized motion data presentation, quantized level of subject A's motion data is gradually changes from 3, 6, and 12. Experiment consists of four sets of trials. In the first trial, subjects craft 3 pieces of paper as a reference data. In second and third trial, subjects craft 8 pieces of paper using either learning method. In the fourth trial, subjects craft 3 pieces of paper without using learning system again (Table 1). Group 1 is subjects who first train with Quantized motion data and group 2 is subjects who first use raw motion data. After 4 sets of trial, we measured the average of difference of weight of 10-cm-square pieces cut off from top and bottom side of a paper in each trial.

Table 1. Learning method for each subject in second trial and third trial

Subjects	2^{nd} *trial*	3^{rd} *trial*
B	Raw motion data	Quantized motion data
C	Quantized motion data	Raw motion data
D	Raw motion data	Quantized motion data
E	Quantized motion data	Raw motion data

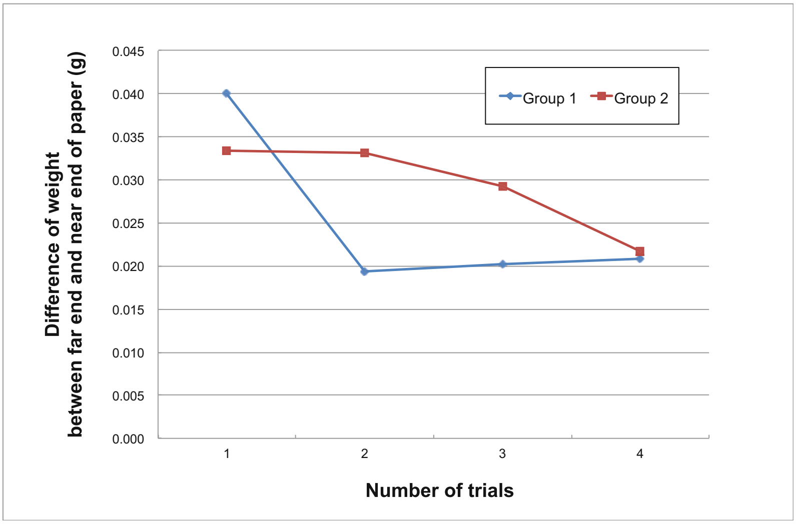

Fig. 7. Average difference of weight of 10-cm-square pieces cut off from top and bottom side of a paper in each trial in each group

As a result, subjects in both group 1 and 2 made a relatively high improvements in paper quality when they used quantized motion data for training. This improvement in skill also remained to each subject even after using proposed learning system.

6 Conclusion

In this research, we measured craftsman's motion of Japanese traditional papermaking and found two remarkable characteristics in motion of expert. We confirmed these two techniques are closely related to quality of papermaking by physical simulation. In order to handing down these two technique, we developed projection based augmented reality display systems that superimposes expert's motion of *sukigeta*. Besides presenting raw motion data of expert, we designed presenting quantized motion data as an indication of target center of oscillation data. From the result of evaluation experiment, quantized motion data presentation made better performance in coaching expert's technique and improved learners papermaking quality. Improved skills of are also successfully remained after using proposed learning system.

Acknowledgments. This research was partially supported by Japan Science and Technology Agency, JST, under Strategic Promotion of Innovative Research and Development Program.

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Estimation of the Facial Impression from Individual Facial Features for Constructing the Makeup Support System

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Abstract. The aim of this study was to construct a makeup support system. This system will show what kind of impression a user's face gives to other persons. Moreover, the system shows how to apply makeup, on the basis of individual facial features, to achieve the ideal impression. In the first step of the research described in this paper, we conducted an experiment in which subjects evaluated facial pictures of eight impressions. On each face, facial-feature points were extracted and used to calculate the ratio of the length and the width of parts of the face. The results of the experiment suggested that the user's impression will be changed by modifying a part of the face by the use of makeup.

1 Introduction

Currently, various makeup methods are introduced in magazines, on television shows, and in You Tube media. These examples portray representations that include *cute*, *sweet-devil*, *cool*, and *gorgeous* women's faces. However, when we try to apply makeup according to these methods, the resulting effect is not always an ideal face.

One of reasons for this less-than-ideal outcome is that our individual faces are different and therefore require different makeup methods. It is not easy for us to recognize our own facial features by ourselves and determine which method is right for us.

There are many kinds of faces: narrow faces and round faces; there are also many kinds of eyes: drooping eyes, up-angled eyes, and wide-open eyes. For example, there is a certain woman whose face is narrow, with a vase-shaped chin. She wants to present herself with a cool impression. If she applies blusher to her cheeks sharply and obliquely, her facial features may be forced and she may not present the cool impression. Namely, it is important to consider our individual facial features, as well as find a good method of makeup, for an ideal result.

Some research shows what kinds of faces people consider to be beautiful [1][2]. Langlois et al. [3] showed that an average face is considered to be beautiful; Grammer, et al. [4] showed that a symmetric face is considered to be beautiful. However, the ideal face that each woman wants to present is not only "beautiful" but also "cool," "cute," and so on.

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 92–99, 2013.

In our research, we aimed to construct a makeup support system. This system enables a user to recognize her individual facial features and discern their individual characteristics (e.g., *Your eyes are smaller than the eyes of a typical women*). Next, this system shows what kind of impression her face gives to other persons. (e.g., *You look like a cute type*). Then, she inputs her ideal impression into the system (e.g., "I want to achieve a cool impression"). The system will show her how to apply makeup on the basis of her facial features (e.g., *You should put on eyeliner thickly*).

The first step of our research, as described in this paper, demonstrates that features of parts of the face have an impact on other people's impression. Nakayama et al. [5] showed that a system user's own preferred face can be estimated from his/her preference for each part of the face. Therefore, first, subjects evaluates facial pictures on eight impressions. A Web service tool extracts 50 facial-feature points of each facial picture. "Facial features" are calculated base on the ratio of the length and the width of a part of a face: face contour, one eye, lips, and mouth of the facial pictures. Then, we analyze the correlations between the eight impressions, the ratios of facial parts, and the eight impressions and the ratio of each facial part, respectively.

2 Experiment

Depending on the facial features, people will have different first impressions. In this section, we describe an experiment in which 20 subjects evaluated 20 facial pictures on eight impressions. The facial features were calculated base on the ratio of the length and the width of a part of a face.

2.1 Method

We prepared 20 facial pictures: 10 of them were pictures of Japanese unknown female talents, e.g., actresses or models; the others were pictures of university students. The faces in the pictures were with makeup. Twenty subjects were university students (10 men and 10 women). The subjects were asked to watch 20 pictures and to complete a questionnaire about facial impressions of each of the pictures. The questionnaire included eight questions to use in evaluating the facial impressions: *kawaii* (cute), *kirei* (beautiful), *kakkoii* (cool), *hanayaka* (gorgeous), *otonappoi* (adult-like), *seiso* (sophisticated), *wakawakashii* (youthful), and *konomidearu* (preference). These impressions were decided by a pre-experiment in which some women told us what they say when giving orders to a makeup artist. The subjects evaluated the pictures, based on these questions, on a 7-point scale (from -3, meaning a weak impression, to +3, meaning a strong impression). They were able to view each picture for an indefinite period of time to evaluate it.

2.2 Correlations between Eight Impressions

The subjects evaluated 20 facial pictures in about 15 minutes, on average. Table 1 and Table 2 show the correlation coefficients between eight impressions on the basis of the evaluation results for 10 of the students' facial pictures and 10 of the talents' facial pictures, respectively. In each table, there are 28 correlation coefficients (28 pairs).

In the correlation coefficients of Table 1, there are significant strong correlations ($p < 0.05$) between 11 pairs, and there are weak correlations ($p < 0.1$) between five pairs. There is no inverse correlation.

In the correlation coefficients of Table 2, there are significant strong correlations ($p < 0.05$) between only three pairs. Moreover, there are significant inverse correlations ($p < 0.05$) between five pairs, and there are weak inverse correlations ($p < 0.1$) between one pair. Seven impressions other than "preference" are divided into four categories: 1. cute and youthful, 2. beautiful, cool, and adult-like, 3. gorgeous, 4. sophisticated.

Table 1. Correlation coefficients between eight impressions on the students' facial pictures

	cute	beauty	cool	gorgeous	adult-like	sophisticated	youthful	preference
cute	1	.867 .001 ***	.437 .207	.777 .008 ***	.010 .977	.717 .020 ***	.808 .005 ***	.914 .000***
beauty	.867 .001 ***	1	.696 .026***	.829 .003 ***	.472 .169 *	.588 .074 **	.498 .143*	.903 .000***
cool	.437 .207	.696 .026 ***	1	.734 .016***	.586 .075 **	.104 .774	.106 .770	.618 .057**
gorgeous	.777 .008**	.829 .003 ***	.734 .016*	1	.404 .246	.607 .063**	.385 .272	.909 .000***
adult-like	.010 .977	.472 .169*	.586 .075 **	.404 .246	1	.097 .791	-.403 .249	.309 .385
sophisticated	.717 .020 ***	.588 .074 **	.104 .774	.607 .063**	.097 .791	1	.441 .202	.771 .009***
youthful	.808 .005 ***	.498 .143 *	.106 .770	.385 .272	-.403 .249	.441 .202	1	.617 .057**
preference	.914 .000 ***	.903 .000***	.618 .057 **	.909 .000 ***	.309 .385	.771 .009 ***	.617 .057 **	1

The upper sections show coefficient correlation rates, and the lower sections show significance probabilities. ***, ** and * show significance level of 0.05, 0.1, 0.2, respectively.

3 Facial Features and Impressions

In this section, we analyze the correlations between the facial features of the facial pictures and the impressions of them by the subjects.

3.1 Extracted Facial-Feature Points

Facial-feature points were extracted using "detectFace(); [6]," a Web service tool. The detectFace(); returns the feature-points data in XML format on the basis

Table 2. Correlation coefficients between eight impressions on the talents' facial pictures

	cute	beauty	cool	gorgeous	adult-like	sophisticated	youthful	preference
cute	1	-.472 .169 *	-.807 .005 ***	.240 .505	-.633 .049***	.243 .498	.816 .004 ***	.525 .119*
beauty	-.472 .169 *	1	.619 .056**	-.351 .320	.899 .000 ***	.330 .351	-.576 .081**	.343 .331
cool	-.807 .005***	.619 .056 **	1	-.173 .633	.777 .008 ***	-.092 .801	-.837 .003 ***	-.313 .379
gorgeous	.240 .505	-.351 .320	-.173 .633	1	-.523 .121 *	-.654 .040 **	.397 .255	.112 .757
adult-like	-.633 .049 ***	.899 .000 ***	.777 .008 ***	-.523 .121 *	1	.375 .285	-.803 .005 ***	.120 .740
sophisticated	.243 .498	.330 .351	-.092 .801	-.654 .040***	.375 .285	1	.046 .899	.435 .209
youthful	.816 .004 ***	-.576 .081 **	-.837 .003***	.397 .255	-.803 .005 ***	.046 .899	1	.272 .447
preference	.525 .119 *	.343 .331	-.313 .379	.112 .757	.120 .740	.435 .209	.272 .447	1

The upper sections show coefficient correlation rates, and the lower sections show significance probabilities. ***, ** and * show significance level of 0.05, 0.1, 0.2, respectively.

of a two-dimensional image. Fig. 1 shows 50 feature points: outline 10, right eye 7, left eye 7, right eyebrow 6, left eyebrow 6, nose 5, and mouth 9.

We did not use the nose data and eyebrow data for face impressions. The impression of the nose is determined based on whether it is high or low, in general. It is difficult to handle three dimensions in our system because our system targets two-dimensional images. Moreover, because some people shave their eyebrows before applying their makeup, the eyebrow data could not be included for evaluation of the impressions.

3.2 Facial Features

Seven facial features were determined from the facial-feature points.

FACE: A short face, a long face or a standard face?
These features are determined by the ratio of the length of the face divided by the width of it. The length means the distance between the hairline (F1) and the tip of the chin (F6). The width means the distance between two points of the outline of the face (F3 and F9). These two points are determined by extending the cheekbones to the outside. The larger the ratio is, the longer the face.

EYES1: Bright eyes, slit eyes, or standard eyes?
These features are determined by the ratio of the width of the right eye divided by its height. The width means the distance between the tail of the eye (ER4) and its corner (ER1). The height is measured through the center

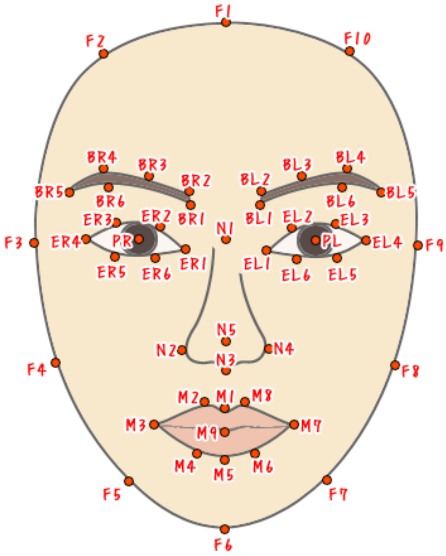

Fig. 1. Facial features' points

of the width of the eye (PR). The larger the ratio is, the more slitted the eye.

EYES2: Big eyes, small eyes, or standard eyes?
These features are determined by the ratio of the width of the face (F3 to F9) divided by the width of one eye. The bigger the ratio is, the smaller the eye.

EYES3: Up-angle eyes, dropping eyes, or standard eyes?
These features are determined by the slope of one eye. The system compare a line segment of the width of one eye (ER1 to ER4) with a line segment of the width of the face (F3 to F9). The larger the positive slope of one eye, the more up-angled the eye. The larger the negative slope of one eye, the more dropped the eye.

CHIN: A round chin, a vase-shaped chin, or a standard chin?
These features are determined by an angle of two line segments: F3-F4 and F5-F6. The larger the angle of two line segments, the rounder the face.

LIPS: Thick lips, thin lips, or standard lips?
These features are determined by the ratio of the width of mouth (M3 to M7) divided by its height (M1 to M5). The width of the mouth means the distance between its left angle and its right angle. The height of the mouth means the distance between the middle of the upper lip and the bottom lip. The larger the ratio is, the thinner the lips.

MOUTH: A large mouth, a small mouth, or standard mouth?
These features are determined by the ratio of the distance between the two pupils (PR to PL) divided by the length of the mouth (M3 to M7). The larger the ratio is, the smaller the mouth.

3.3 Correlation Coefficients between Seven Features

Table 3 shows the correlation coefficients between seven features on the basis of the results of evaluations by 20 subjects. This table indicates a significant correlation between FACE and EYES2. However, we can see the other pairs have no significant correlation. Namely, these seven features are almost independent.

Table 3. Correlation coefficients between seven features

	FACE	EYES1	EYES2	EYES3	CHIN	LIPS	MOUTH
FACE	1	.202 .394	-.590 .006 ***	-.037 .877	.320 .169 *	-.189 .424	.108 .650
EYES1	.202 .394	1	-.268 .253	.141 .552	-.145 .542	-.292 .212	.172 .469
EYES2	-.590 .006 ***	-.268 .253	1	-.181 .444	-.104 .663	.046 .846	-.047 .843
EYES3	-.037 .877	.141 .552	-.181 .444	1	-.259 .270	.067 .780	.058 .807
CHIN	.320 .169*	-.145 .542	-.104 .663	-.259 .270	1	-.351 .129*	-.234 .320
LIPS	-.189 .424	-.292 .212	.046 .846	.067 .780	-.351 .129*	1	-.015 .948
MOUTH	.108 .650	.172 .469	-.047 .843	.058 .807	-.234 .320	-.015 .948	1

The upper sections show coefficient correlation rates, and the lower sections show significance probabilities. ***, ** and * show significance level of 0.05, 0.1, 0.2, respectively.

3.4 Correlation Coefficients between Seven Features and Eight Impressions

Table 4 and Table 5 show the correlation coefficients between seven features and impressions in the students' pictures and in the talents' pictures, respectively.

In the students' pictures, there are significant correlations ($p < 0.05$) between three pairs: cool-FACE, cute-LIPS, and beautiful-LIPS. These results suggest that a long face gives the impression of cool and thin lips give the impressions of cute and beautiful.

In the talents' pictures, there are significant correlations ($p < 0.05$) between four pairs: sophisticated-EYES2, sophisticated-EYES3, like-EYES3, and gorgeous-LIPS. These results suggest that big eyes give the impression of sophisticated, up-angled eyes give the impression of sophisticated (the preference), and thin lips give the impression of gorgeous.

Table 4. Correlation coefficients between seven features and impressions in the students' pictures

	cute	beauty	cool	gorgeous	adult-like	sophisticated	youthful	preference
FACE	.457*	.494*	.723***	.586**	.244	.007	.465*	.539*
	.184	.147	.018	.075	.498	.985	.175	.108
EYES1	.116	-.148	.061	.105	-.334	.330	.271	.179
	.749	.684	.867	.772	.345	.352	.448	.621
EYES2	-.248	-.192	-.009	-.159	-.195	-.257	-.452*	-.331
	.489	.596	.980	.661	.589	.473	.190	.351
EYES3	.165	.069	-.115	-.187	-.124	.137	.527*	.149
	.650	.850	.752	.605	.733	.706	.117	.681
CHIN	-.345	-.136	-.251	-.344	.173	-.260	-.560**	-.411
	.329	.707	.484	.331	.632	.469	.092	.239
LIPS	.647***	.726***	.197	.374	.292	.534*	.435	.545*
	.043	.017	.585	.287	.412	.112	.209	.103
MOUTH	.285	.161	.337	.208	-.155	-.168	.549*	.272
	.425	.656	.340	.564	.670	.642	.100	.447

The upper sections show coefficient correlation rates, and the lower sections show significance probabilities. ***, ** and * show significance level of 0.05, 0.1, 0.2, respectively.

Table 5. Correlation coefficients between seven features and impressions in the talents' pictures

	cute	beauty	cool	gorgeous	adult-like	sophisticated	youthful	preference
FACE	-.456	.162	.238	.220	.092	-.385	-.208	-.129
	.185*	.656	.508	.542	.800	.271	.564	.722
EYES1	.053	-.144	.174	.276	-.097	-.406	-.226	.114
	.883	.692	.631	.441	.790	.244	.531	.754
EYES2	.215	-.039	-.033	-.462	.199	.690	-.085	.064
	.551	.914	.927	.178*	.582	.027***	.815	.861
EYES3	.547	-.076	-.314	-.058	-.058	.636	.397	.652
	.102*	.834	.378	.873	.874	.048***	.257	.041***
CHIN	-.506	-.086	.188	.251	-.006	-.445	-.189	-.207
	.135*	.813	.604	.484	.986	.197 *	.602	.565
LIPS	-.061	.194	.187	-.758	.325	.316	-.264	-.292
	.866	.592	.604	.011***	.360	.373	.460	.413
MOUTH	-.119	-.322	.190	.009	-.212	-.088	.020	-.501
	.744	.365	.599	.980	.557	.809	.957	.140*

The upper sections show coefficient correlation rates, and the lower sections show significance probabilities. ***, ** and * show significance level of 0.05, 0.1, 0.2, respectively.

4 Discussions

The results of correlations between eight impressions are different between the students' pictures and the talents' pictures. In the students' pictures, "preference" has strong correlations with the other seven impressions. These results indicate that degrees of fine-looking are very different between the students' pictures. Preferred faces are inclined to be evaluated better on all the impressions. On the other hand, because the talents' faces are fine-looking, on the whole, the evaluations for the impressions are almost divided. The results suggest that the talents' facial features are helpful for determining how to apply makeup to attain a specific impression.

The results of correlations between eight impressions and seven facial features show that some methods are associated with specific impressions. For example, the face associated with the "cute" impression consists of a short face, up-angled eyes, and a vase-shaped chin. Namely, it is suggested that the user's impression can be changed by modifying a part of the face by the use of makeup.

Unfortunately, there few pairs that have significant correlations because we prepared only 20 pictures for this experiment. If we prepare more pictures of talents, as well as the impressions of four categories (see Sec. 2.2), we may discover more methods of modifying a part of the face to achieve a specific ideal impression.

5 Conclusion

In this paper, we described an experiment in which we asked subjects to evaluate 20 facial pictures on the basis of the following facial impressions: cute, beautiful, cool, gorgeous, adult-like, sophisticated, youthful, and preference. Moreover, each facial picture was given "facial features" on the basis of facial-feature points of the face contour, one eye, lips, and a mouth. Finally, we analyzed correlations between the impressions and the facial features. The results suggested that the user's impression can be changed by modifying a part of the face by using makeup.

In the future, we will construct a makeup support system that shows what kind of impression a user's face gives to other persons and how to apply makeup on the basis of her individual facial features to achieve her ideal impression.

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User Guiding Information Supporting Application for Clinical Procedure in Traditional Medicine

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Abstract. Medical diagnostic procedures generally comprise a step of collecting patients' symptoms, a step of diagnostic decisions, and a step of selecting appropriate methods of treatment. In traditional medical treatment based on analogical inference, analyzing present collected symptoms and choosing symptoms to query are mightily important for the diagnosis and these are essential conditions for appropriate treatment. Use of information systems that support present diversity of symptoms information and considerable options for the next step can avoid missing out timely and useful knowledge during the procedures. We have developed an application that having user interfaces guiding various analytic cases and their next optional choice and clinicians are able to improve the efficiency of procedures with this. By analyzing semantically linked data to symptoms, the application is possible to support efficiently collecting symptoms and selecting methods of treatment. This interfaces help users by requiring a minimal operation but supporting diverse probabilities.

Keywords: User guiding, Decision support, Ontology, Traditional medicine, Korean medicine.

1 Introduction

A medical diagnosis, in the sense of diagnostic procedure, can be regarded as an attempt at classification of an individual's condition into separate and distinct categories that allow medical decision about treatment and prognosis to be made [1, 2]. Numerous studies have been done on medical diagnosis, including improving itself by various approaches [3–8]. The initial task is to detect medical indication to perform a diagnostic procedure. Medical indication includes patients' symptoms present in them currently, their physical information, and their past medical history. This information is designed to accurately describe the overall patient condition and form the basis of diagnostic data. Modern medicine doctors may make decision on whether to determine which diagnostic examination is required for the patient [9].

Unlike modern medicine [10], traditional medicine doctors make a diagnosis by analyzing collected medical indication, that is to say patient's symptoms [11]. In spite of the fact that the most basic step in procedure of medical diagnosis by traditional

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 100–109, 2013.

medicine doctors is detecting patients' symptoms, traditional medicine doctors have a low level of dependence on diagnostic devices because of various barriers including legal constraint, tradition and lack of standards [12]. This is why both patients' appeals and some diagnostic process including tong diagnosis and pulse diagnosis are very important elements in traditional diagnostic procedure. Moreover, lots of symptoms dealt in the traditional way, such as thirst, dry mouth, sweating or no sweating, and yellow urine are very ordinary but good criteria of patients' health.

Therefore, proper symptom collection including ordinary condition is an essential factor for precise treatment, and it will be helpful if a supporting system provide necessary information for collecting symptoms from patients. And after decision of classification, it will be also helpful if the system provide necessary information for determining a method of treatment and for deciding a formula because there are various methods and formulas for treating a disease that is distinguished by patients' condition.

2 Materials and Methods

The general composition of knowledge in Traditional Korean Medicine (TKM), excluding basic theoretical concepts, consists of medications, acupuncture points, symptoms, and diseases (or patterns) [13]. Fig. 1 illustrates this general composition of TKM knowledge, where a node represents class or instance and a link represents a property. Because pattern in TKM or traditional Chinese medicine (TCM) is similar to disease, it was omitted from the graph in Fig. 1 to increase visibility. And because relations among concepts are possible to be analyzed bilaterally, the directivity of properties was also omitted.

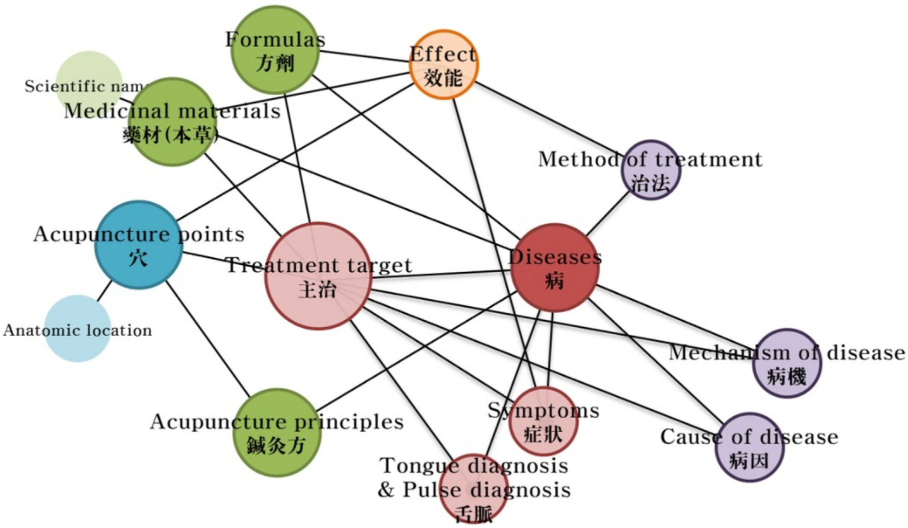

Fig. 1. A graph of the TKM knowledge

Treatment targets, objects of major indication of treatment, are often represented as a combination of diseases, symptoms, or causes of disease and symptoms cannot be simply expressed as dealt with a medicinal material or a formula. A disease contains symptoms that can appear in patients, causes, mechanisms, and methods of treatment. Medicinal materials, formulas, and acupuncture points contain information on effects as treatment methods, as well as information on the treatment target or disease. Methods of treatment are linked to the corresponding proper effects of treatment, whereas treatment targets can be linked to the proper diseases, symptoms, diagnoses, or causes of a disease.

Medical literature on TKM, such as Donguibogam and present textbooks, has described diseases (or patterns) and their treatment information. But each book is focusing on describing one among diseases, formulas, or medicinal materials even though all kind of diseases, formulas and medicinal materials are dealt in them. Ontologies of diseases, formulas, medicinal materials, or acupuncture points can be built based on these features. But it cannot be easily declared that a formula treating a symptom is identical to a formula known to treat a disease involving this symptom even though the names of these two formulas are same.

Traditional medicine knowledge of this character is described in lots of books and the contents of these books are organized according to the table of contents. Thus text cannot provide necessary comprehensive information at an appropriate time, even when information retrieval systems are used. After searching is conducted many times by a doctor, relevant information is integrated on a node, such as a disease, a formula, and a symptom.

The abovementioned manner of utilizing knowledge requires a continuous information retrieval process, and many difficulties are encountered when integrating and utilizing a series of concepts obtained in this manner, which makes it unreasonable to use this type of knowledge in clinical practice. From the perspective of computer engineering, such separated knowledge can be built into a number of ontologies and integrated knowledge, as shown in Fig. 1, can be reproduced by linking these ontologies together.

To achieve this, the resource description framework (RDF) [14] was used to build TKM ontology, and the Jena Ontology application programming interface (API) was used to process appropriate data. The ontologies of medicinal materials, formulas, or disease described above were linked together by experts in TKM to prevent any restriction in accessing the linked data or ontologies from the systems perspective. In the real world, each element of the expert knowledge will be published by the experts in each field and could be represented as fused knowledge through a mutual connection.

2.1 Supporting Suitable Knowledge for Collecting Symptoms

Patient symptom collection is roughly divided into two cases. One is collection from appealed by patients and patients recognize these symptoms themselves. Another one is collection from queried by doctors and doctors gather these symptoms by reasoning and examination. Doctors' collecting may be repeated in processes of diagnosis and treatment determination.

A patient suffers from one disease or from a number of diseases like a complication. A doctor can presume a number of diseases the patient suffers from by analyzing appealed symptoms. From that, the doctor can query additional symptoms which are not appealed at that time for determining one result or can exclude symptoms which are neither related with the presumed disease nor appealed by the patient. Some of appealed symptoms could be excluded if those symptoms might be ignored or analyzed to mistaken symptoms.

In the step of collecting symptoms, the supporting system can suggest candidate presumed diseases which have collected symptoms by using linked data. Linked data enables the system to sort these diseases in order of having more collected symptoms and to suggest symptoms for reducing candidates. Adding a symptom which is accompanied in most candidate diseases leads to exclude a few candidates and adding a symptom which is accompanied in few candidate diseases leads to exclude a lot of candidates. At this point, doctors select a next proper symptom based on candidate diseases, neither by the number of matched symptom nor by the number of candidate diseases. Fig. 2 shows this flow. Fig. 3 shows a user interface for this step.

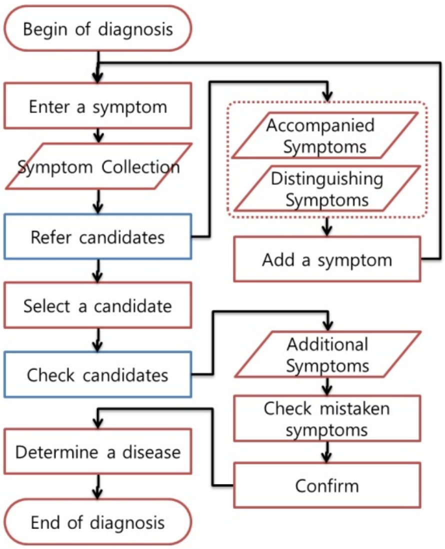

Fig. 2. A flowchart of collecting symptoms from a patient

Fig. 3. A user interface of collecting symptoms

2.2 Supporting Suitable Knowledge for Deciding Treatment

In the step of determining the methods of treatment after diagnosis, formulas linked to the collected symptoms or formulas linked to the decided diagnosis results can be selected. As shown in Fig. 1, information regarding the given formulas is initially given for the disease. After a treatment method is selected by the doctor, effects linked to the treatment method are searched, and additional formulas with corresponding effects can be found.

Moreover, if the major indications of the searched formulas were analyzed and it was found such that there is a match between the information on the linked disease from the searched formula and the disease as a result of a diagnosis, then the selection of the corresponding formulas can be presented as an appropriate choice. The formulas linked to the collected symptoms can be selected from among the possible selections.

As shown in Fig 4, this is why there are more reasonable treatments by considering cause of disease, mainly appealed symptoms, and their aspect depending on the patient among a number of treatments linked with a disease as a diagnosis result.

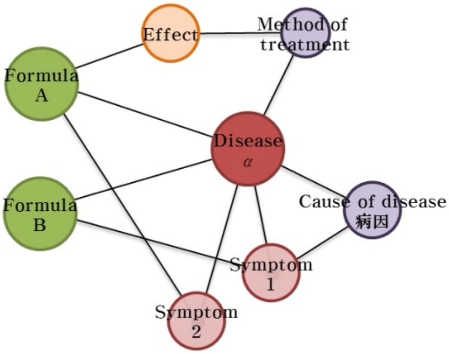

Fig. 4. An example of determining a proper treatment

When symptom 1 in Fig. 4 is a mainly appealed symptom and symptom 2 is not accompanied, then formula B is more proper. When a doctor determines a method of treatment and a corresponding formula having proper effect is formula A, formula A could be considered. Fig. 5 shows a user interface for this step.

Fig. 5. A user interface of deciding a formula

3 Results and Discussion

3.1 Collecting Symptoms

We supposed that two symptoms “feeling cold” and “fever” were collected by a patient’s appealing. In current TKM ontologies, there are ten diseases accompanying both two symptoms and 46 additional symptoms could be accompanied with these ten diseases. Table 1 shows accompanied symptoms and their frequency. The two symptoms above could be accompanied with ten diseases but other symptoms could be accompanied with up to five diseases.

Table 1. Symptoms accompanied with given symptoms “feeling cold” and “fever”

Symptoms accompanied with 5 diseases	Symptoms accompanied with 4 diseases	Symptoms accompanied with 3 disease
headache	no sweating	cough, asthma

If a doctor supposes that the patient has a headache or one of candidate is possible, then he should check whether the patient has a headache or not. If the patient has a headache, the system returns information shown in table 2. There are five diseases accompanying all three symptoms. A disease not accompanying headache should be excluded.

Table 2. Symptoms accompanied with given symptoms “feeling cold”, “fever” and “headache”

Symptoms accompanied with 3 diseases	Symptoms accompanied with 2 diseases	Symptoms accompanied with only one disease
no sweating	-	cough, dry mouth, pain in the chest, dizziness, etc.

After the doctor check whether the patient has sweating or not, he could make a decision or check more symptoms in the same way. If the patient has not a headache and has a cough, then the system returns information shown in table 3 instead of table 2. In this case, the number of candidate diseases is three.

Table 3. Symptoms accompanied with given symptoms “feeling cold”, “fever” and “no sweating”

Symptoms accompanied with 2 diseases	Symptoms accompanied with only one disease
asthma	headache, dry mouth, pain in the chest, dizziness, etc.

If the doctor checked the patient has not a headache in the previous step, the system let him know the only one disease accompanying a headache and he could determine whether the disease should be excluded or not. By showing this kind of further information, the system does support doctors and providing proper knowledge at the right time.

3.2 Deciding a Formula

We searched formulas from the TKM disease ontology by a symptom and then searched after linking effect to method of treatment. This result shows more information can be obtained by linking data not merely because an additional ontology was used. By linking medicinal materials used for diseases to formulas, more formulas can be retrieved.

The primary property statistics for finding formulas to care symptoms in the disease ontology are shown in Table 4 and Table 5.

Table 4. Number of formulas to care cough

Number of having effect to "cough"	Number of diseases having cough	Number of formulas treat diseases having cough
22 (a)	56	109 5 overlapped with (a)

Table 5. Number of methods of treatment for diseases having cough

Number of methods for 56 diseases having cough	Number of effects EXACTLY corresponding these treatment methods	Number of formulas having these effects
58	12	43 10 overlapped with above 136

From the TKM disease ontology, 109 referable formulas from diseases having cough were found and 58 methods of treatment were found. It is dependent on how to find effects corresponding to these methods, but 12 effects were linked by name. From the TKM formula ontology, 43 formulas having these effects were found and 8 formulas were overlapped. But, 35 referable formulas could be presented after linking.

Knowledge regarding TKM is largely based on traditional medical literature, and such knowledge actually exists independent of TKM. This information exists in the minds of Korean medicine doctors through the incorporation and interpretation of such knowledge, and the interpretation and application of TKM theory is determined by Korean medicine practitioners. However, knowledge based on traditional medical literature, as well as clinical knowledge, must be accumulated and shared by linking these types of knowledge to achieve the standardization and objectification of traditional medicine.

If the knowledge discussed in Section 2 is divided and expressed in a different space in which the data storage or access methods are varied, and the management of the knowledge is conducted independently, it will be virtually impossible to integrate and manage such knowledge; therefore, it will be extremely difficult to merge and use elements of knowledge that are not linked.

However, if each piece of knowledge is shared or linked using a unique uniform re-source identifier (URI) through RDF/OWL [15], this knowledge can be readily accessed on the Web, and each set of data can be shared rather than becoming subordinate to a specific system [16]. Furthermore, knowledge that is made public or shared based on a URI would be reviewed and refined by many individuals and could be realized as user-agreed knowledge. The introduced information supporting system also could be utilized efficiently in process of treatment including collecting symptoms and determining treatment by providing proper knowledge.

Acknowledgments. This research was supported by a Grant-in-Aid from the Korea Institute of Oriental Medicine (No. K12090).

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Designing and Verifying Application Schema by Applying Standard Element for Managing Ocean Observation Data

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Abstract. There is a need to study the OWL-based application schema to ensure interoperable data exchange between ocean-related institutions, and supporting researcher's intelligent data search. In this study, the RDF vocabularies are defined on the basis of the elements derived through element decision study for managing scientific data in the field of ocean observation. The application schema was verified by using the temperature profile data of CTD data observed in the 'Chukchi' sea selected from the data provided by the National Oceanographic Data Center of the US.

Keywords: Scientific Data, Observation Data, Ocean Observation Data, Application Schema, OWL Schema, Metadata.

1 Introduction

It is necessary to establish ocean observation data as Linked Data so as to make the data a model case (Bizer 2009) for connecting structured data on the web and to be published. In this study, an OWL-based application schema will be designed and verified in order to ensure interoperable data exchange between ocean-related institutions and to support researchers' intelligent data search. The determined standard elements are defined on the basis of the elements derived through element decision study for managing scientific data in the field of ocean observation. The higher 21 elements and the lower 173 elements which are the basis for defining vocabularies are found in http://bit.ly/GTuSvi.

2 Designing Application Schema

2.1 Class Design

A vocabulary dictionary is established, which consists of 21 class concepts, 50 object attributes and 92 data type attributes for the metadata standard elements in order to

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 110–115, 2013.

design an application metadata schema, and to present it at http://bit.ly/uMOxkD. Class design was carried out as follows. <owl:Class> and <rdfs:subClassOf> was used to design the following class. ② and ⑤ define the standard elements “Institution, Person”. Each element is the lower class of the common higher element <Agent>, and is defined with the RDF schema vocabulary, <rdfs:subClassOf>, as in ③. ① is the URI declaration for the basic Namespace used in designing RDF OWL schema.

```
<rdf:RDF
omitted…
xmlns="http://www.kisti.re.kr/ontology/scientificdata.owl#" …… ①
xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#">
<owl:Class rdf:ID="Institution"> ........................................... ②
<rdfs:subClassOf> ................................................................ ③
<owl:Class rdf:ID="Agent"/> ................................................ ④
</rdfs:subClassOf>
</owl:Class>
<owl:Class rdf:ID="Person"> ................................................ ⑤
<rdfs:subClassOf rdf:resource="#Agent"/> ............................ ⑥
</owl:Class>
```

Fig. 1. Design Agent related class

2.2 Designing Object Value-Type Attribute

<owl:ObjectProperty> and <rdfs:subPropertyOf> was used to design the following object value type attribute.

```
<owl:ObjectProperty rdf:ID="hasCreator"> .......................... ①
  <rdfs:subPropertyOf> ................................................ ②
   <owl:ObjectProperty rdf:ID="hasAgent"/> ...................... ③
  </rdfs:subPropertyOf>
  <rdfs:comment
rdf:datatype="xsd:string">producer</rdfs:comment>……….. ④
 </owl:ObjectProperty>
 <owl:ObjectProperty rdf:ID="hasPublisher"> ..................... ⑤
  omitted…
 </owl:ObjectProperty>
```

Fig. 2. Design hasAgent related object value type attribute

① and ⑤ is to define “hasCreator, hasPublisher” as an object value type attribute to state the producer and publisher information of the standard element <Agent>. Each attribute is the lower attribute of the common higher attribute <hasAgent>, and the higher element was specified with the RDF schema vocabulary, <rdfs:subPropertyOf>, as shown in ③. ④ describes that the ‘producer’ information is stated as the value of object value type attribute hasCreator, using <rdfs:comment> so that humans and systems can understand and process the defined attributes.

2.3 Designing Data Value Type Attribute

The following details of design show definition of data value type attributes by using <owl:DatatypeProperty> and <rdfs:subPropertyOf>. ① and ⑤ defines data value type attributes corresponding to the standard elements “uniformTitle, alternateTitle”. Each of them is the lower attribute of the common higher attribute <title>, and is defined by using the RDF schema vocabulary, <rdfs:subPropertyOf>, as shown in ③. ④ represents the higher attribute.

② and ⑥ applies “rdfs:domain, rdf:resource” of the RDF schema to represent the attribute so as to define resources that the defined data value type attribute can have as a domain. ⑦ uses the owl:cardinality attribute to define a restriction of the number of the title attribute appearances, which means that classes, such as ScientificData that uses the title attribute, can be stated by using the title attribute only once.

```
<owl:DatatypeProperty rdf:ID="uniformTitle"> ........................ ①
  <rdfs:domain rdf:resource="#ScientificData"/> ..................... ②
  <rdfs:subPropertyOf> .............................................. ③
    <owl:DatatypeProperty rdf:ID="title"/> .......................... ④
  </rdfs:subPropertyOf>
 </owl:DatatypeProperty>
 <owl:DatatypeProperty
rdf:ID="alternateTitle"> ............................................ ⑤
  <rdfs:subPropertyOf rdf:resource="#title"/>
  <rdfs:domain rdf:resource="#ScientificData"/> ..................... ⑥
 </owl:DatatypeProperty>
 <owl:Restriction> .................................................. ⑦
  <owl:onProperty rdf:resource="#title"/>
  <owl:cardinality
rdf:datatype="xsd:nonNegativeInteger">1</owl:cardinality>
```

Fig. 3. Design Title related data value type attribute

3 Verifying Selected Element

To verify the OWL application schema, the test for creation of RDF document which follows the schema was conducted. The test dataset, the temperature profile data of CTD data observed in the 'Chukchi' sea selected from the data provided by the National Oceanographic Data Center of the US, were used. All about 10,189 records were collected.

The shape of the collected data is as below. ① is about the platform at which observation was conducted. ② is about the institute which is chare of data creation. ③ is about the project name which supply the fund for observation. ④ is about the depth of the deployment. ⑤ is about start datatime and end datatime of the observation. ⑥ is about latitude and longitude at which observation was taken. ⑦ is about bottom depth of the sea. ⑧ is about number of records which a dataset has. ⑨ is about recording interval. In this example, the observation was taken place per 1 hour. ⑩ is about the records. In this example, the data were collected per 60 minutes which consists of 8774 records.

① Platform: moored buoy
② Institute: University of Alaska/Institute of Marine Sciences
③ Project Name: CHUKCHI94
④ Deployed Depth: 55 Meters
⑤ Start Date/Time: 25-sep-1993 03:00:00
End Date/Time: 25-sep-1994 16:00:00
⑥ Latitude: 71 03.23 N
Longitude: 159 31.90 W
⑦ Bottom Depth: 75 Meters
⑧ Number of Records: 8774
⑨ Recording Interval: 60 Minutes

no.	Date	Time	Depth	Temp.	Cond.	Sal.	Sigma T
336	25-sep-1993	03:00:00	55.0	5.2198	30.1902	31.0109	24.4906
337	25-sep-1993	04:00:00	55.0	5.3319	30.2183	30.9390	24.4214
338	25-sep-1993	05:00:00	55.0	5.2659	30.2401	31.0247	24.4965
339	25-sep-1993	06:00:00	55.0	5.0859	30.1215	31.0571	24.5416

⑩

Fig. 4. The example of ocean observation data

The figure 4 is showing the procedure of RDF document creation. The crawler ingest the data from the NOAA web site. It collected the data and build the database, simultaneously made a log file as shown below in ①, ② and ③ process. Instance generator read the records from the database as in ④ process and create RDF document which follow the Turtle format as in ⑤. It makes a log file also as Crowler as in ⑥.

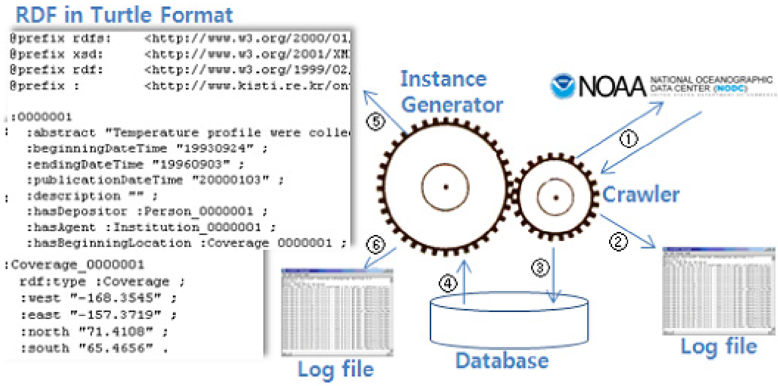

Fig. 5. The procedure of RDF Document Creation

The following shows an RDF document of 'ttl type' created with the instance creator and an RDF document of RDF/XML type created by using the RDF verifier and a converter provided at 'http://www.rdfabout.com/'.

```
# Verify ttl type
@prefix :      <http://www.kisti.re.kr/ontology/scientificdata#>.
:SD0000999
  :title "Chlorophyll data collected by the research vessels … May -
September 2002 " .
  :beginningDateTime "20020414" ;
  :hasBeginningLocation :Coverage_0000999 ;
  :hasSource :Source_0000999_1, :Source_0000999_2;
:Coverage_0000999
  rdf:type :Coverage ;
  :west "-77.76" ;   :east "-65.5" ;   :north "-65.12" ;
<omitted...>

# Verify RDF/XML type
<rdf:Description
rdf:about="http://www.kisti.re.kr/ontology/sd#SD0000999">
   <sd:title>
     Chlorophyll data collected by the research vessels … May -
September 2002
   </sd:title>
   <sd:hasBeginningLocation>
     <sd:Coverage
rdf:about="http://www.kisti.re.kr/ontology/sd#Coverage_0000999">
       <sd:west>-77.76</sd:west>  <sd:east>-65.5</sd:east>
<sd:north>-65.12</sd:north>
     </sd:Coverage>
```

Fig. 6. Design Agent related class

The above test demonstrated that the RDF document for applying the OWL-based application metadata profile designed in this study was successfully created by using the data provided by the National Oceanographic Data Center of the US (NODC) as input.

4 Conclusion

In this study, the OWL-based metadata application schema was designed by using the metadata standard element for managing and using ocean observation data. The application schema was verified for the data provided by the NODC. The data of the NODC actually used was verified. We also proved that the selected metadata element and the application schema were actually applicable without modification. When NODC's metadata elements were tested and compared with the metadata elements selected in this study, all CDT data could be described by these elements like 'SourceName', 'Project', 'DeployedDepth', 'DataItem', 'TimeInterval', 'BottomDepth', 'ObservationLocation' etc. And each application schema also described without missing elements.

Therefore, derived metadata standard elements for the ocean observation field are judged to be full of significance and expected to be utilized for metadata management and practical use in the field of ocean observations. The application schema proposed in this study will be useful for managing and using metadata involved in ocean observation.

Acknowledgment. This essay is a modified version and summary of a graduate school thesis, Chonbuk National University (February 2, 2012).

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Usability of Performance Dashboards, Usefulness of Operational and Tactical Support, and Quality of Strategic Support: A Research Framework

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Abstract. Performance dashboards are used as a strategic decision support tool in organizations. In this research, we examine the relationships between the usability of performance dashboards, the usefulness of operational and tactical support, and the quality of strategic support that they provide. We hypothesize that usability of performance dashboards will influence user perceptions of the usefulness of the operational and tactical support provided by the dashboards, which in turn influence the perceived quality of strategic support provided.

Keywords: Performance Dashboards, Usability, Data Visualization, Strategic Support, Tactical Support, Operational Support.

1 Introduction

Performance dashboards that are built on business intelligence platforms with integration tools to leverage rich data from a company's ERP systems play an important role in today's Executive Information Systems (EIS) (Watson, 2011). EIS facilitate and support executives in decision making to effectively and efficiently manage business activities such as planning, measuring, communicating, and monitoring business results. As the majority of executives, managers and decision makers are non-technical IT users with time constraints and tight schedule at work (Marx et al., 2011), visually appealing graphics rich performance dashboards that provide information in a user friendly format with virtually no learning curve play an important role in disseminating information effectively and efficiently.

Performance dashboards are often regarded as the modern version of EIS and are used to provide operational, tactical or analytical, and strategic support for management (Lea, 2012; Eckerson, 2011). As a variety of visual cues, graphs, gauges, icons, and images are utilized to provide visually appealing display in a performance dashboard (Few, 2006), usability of a performance dashboard becomes important because it can have an impact on the performance dashboard's usefulness in supporting decision making. This study hypothesizes that the usefulness of operational support and

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 116–123, 2013.

tactical support are influenced by the usability of performance dashboards and that the usefulness of operational and tactical support will have an impact on the quality of strategic support.

2 Literature Review

2.1 Usability

Various definitions of usability have been used in the literature. Nielsen (1994) defines usability as a quality attribute that assesses *how easy it is to use a user interface*. He defines usability based on five quality components (Nielsen, 2012):

- Learnability: How easy is it for users to accomplish basic tasks during first use?
- Efficiency: Once users have learned the design, how quickly can they perform tasks?
- Memorability: When users return to the design after a period of not using it, how easily can they re-establish proficiency?
- Errors: How many errors are made, how severe are these errors, and how easy is it to recover from the errors?
- Satisfaction: How pleasant is the interface?

Hence, Nielsen's definition of usability refers to how easy and pleasant an interface is. In this research, we will adopt Nielsen's definition and conceptualization of usability.

For completeness, we will review other common definitions and conceptualizations of usability and then justify why they are not adopted for this research.

The International Organization for Standardization (ISO 9241-11) defines usability as "The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use." (Karat, 1997, p. 34) The ISO definition of usability is not only specific to user and context, but it is also dependent on the goal. Since it can be difficult to accurately assess goals (i.e., even users may not be able to articulate their goals or may not be clear about their goals), not to mention assessing fulfillment of goals, we find the operationalization of ISO's definition of usability to be an empirical challenge. To date, we have not come across any empirical operationalization of usability as a formative construct comprising effectiveness, efficiency, and satisfaction, as suggested by ISO. Studies have assessed effectiveness, efficiency, and satisfaction but not having them as formative dimensions of usability.

Agarwal and Venkatesh (2002) used the Microsoft Usability Guidelines (MUG) to assess Web usability. The MUG are comprised of content (relevance, media use, depth and breadth, current and timely information), ease of use (relating to clear and understandable objectives, structure, and feedback), promotion (website advertising), made-for-the-medium (community, personalization, and refinement), and emotion (challenge, plot, character strength, and pace). Because of the multi-dimensionality of the MUG where not all criteria are equally important across different types of users and Web sites, evaluative criteria are needed to provide an assessment of the relative importance (or weights) of the different categories. Such evaluative criteria may be subjective and are dependent on a variety of factors such as user goals, user types, and types of interface. To remove subjectivity in determining the multidimensional assessment of usability, we will focus on ease of use in this research, which is in line with Nielsen's definition of usability.

2.2 Usefulness

Usefulness of decision support is an important construct for any system that offers decision support capabilities (Elbeltagi et al., 2005; Ruland and Bakken, 2002). In order for such a system to be accepted and adopted by users, the system needs to be perceived to be useful by users (Elbeltagi et al., 2005). In the context of this research, we will examine the perceived usefulness of different types of support presented by a performance dashboard.

2.3 Dashboard

A performance dashboard is defined as a multilayered interactive visual display mechanism built on a business intelligence and data integration infrastructure that conveys key performance information at a glance to allow users to effectively measure, monitor, and manage business performance of an organization toward predefined goals (Lea, 2012; Eckerson, 2011; Few, 2006). Similar to EIS, performance dashboards aim to deliver the right information to the right users at the right time in order to (i) optimize decision making, (ii) enhance operational efficiency (Lea, 2012), (iii) improve data visibility, process transparency, and strategy communication and alignment (Eckerson, 2011), (iv) reduce costs and resources required to prepare performance reports and management business (Eckerson, 2011; Pauwels et al., 2009), and (v) improve profitability.

Performance dashboards are often considered the successor of EIS (Few, 2006; Marx, et. al., 2011) and are regarded as one of the effective presentation layers of business intelligence as they are easily understood and require minimal or no training for users (Eckerson, 2011; Chaudhuri et al., 2011; Marx et al., 2011). Performance dashboards are commonly classified into three categories: Operational dashboards, Tactical, or Analytical dashboards, and Strategic dashboards to provide operational, tactical, and strategic decision support respectively (Lea 2012; Eckerson, 2011). Eckerson (2011) indicated that more than two thirds of survey respondents indicated that they use all three types of dashboards in their organizations with 80% in the form of tactical dashboards, 64% in the form of strategic dashboards, and 59% in the form of operational dashboards. Operation support focuses on monitoring business operations and activities through data visualization, results interpretation, report preparation, trends analysis, and flexibility to create additional charts, reports, and statistics, and thus often requires information with a high level of detail in real time or near real time. Tactical or analytical support utilize periodic snapshots of data to provide managers with functions to identify trends, patterns, or causes of problems to measure progress of their organization toward predefined goals, so traceability, accountability, communication, timely information, and flexibility in information details are key characteristics. Strategic support provides managers with tools to map the company's mission and strategies with objectives, measures, and initiatives and to monitor and communicate strategy execution (Kaplan and Norton, 1996).

An effective EIS implemented as a performance dashboard system enables vertical cascading and horizontal cascading for operational, tactical, and strategic support (Eckerson, 2009). Vertical cascading enables employees at all levels to understand how their efforts contribute to the company as a whole through the use of the same Key Performance Indicators (KPIs) across the dashboards of different levels. Horizontal cascading aligns the KPIs among all independent or interconnected dashboards to achieve the greatest degree of coordination possible and to bring together top-down strategic scorecard initiatives that can help to manage strategy with bottom-up dashboard projects that manage processes (Eckerson, 2009).

Vertical cascading and horizontal cascading could be operationalized through the use of three interconnected information layers: summarized graphical view, multidimensional analytical view, and detailed transactional data view (Eckerson, 2011) to present information differently or interactively for different users and for different purposes (Lea, 2012). Starting from the summarized graphical view (top layer), each successive layer provides additional details, views, and perspectives that help users to understand a problem better and to identify the steps needed to solve it, as shown in Fig. 1.

3 Theoretical Background and Hypotheses

The literature and empirical support on Technology Acceptance Model (TAM) has shown that usability (or ease of use) influences perceived usefulness (Davis, 1989). Marx et al. (2011) and Houdeshel and Watson (1987) suggested that ease of use is one of the key design principles for a successful EIS implemented as performance dashboards. As an extension of the prior literature, we hypothesize that usability (or ease of use) is a major factor influencing the perceived usefulness of operational and tactical support in the context of a performance dashboard. Hence, the following hypotheses are generated.

Hypothesis 1 (H_1): Usability of a performance dashboard influences the perceived usefulness of operational support.

Hypothesis 2 (H_2): Usability of a performance dashboard influences the perceived usefulness of tactical support.

As presented in the previous section, the strategic support provided by a performance dashboard relies on its operational and tactical support through the use of three interconnected information layers. In other words, a performance dashboard is a

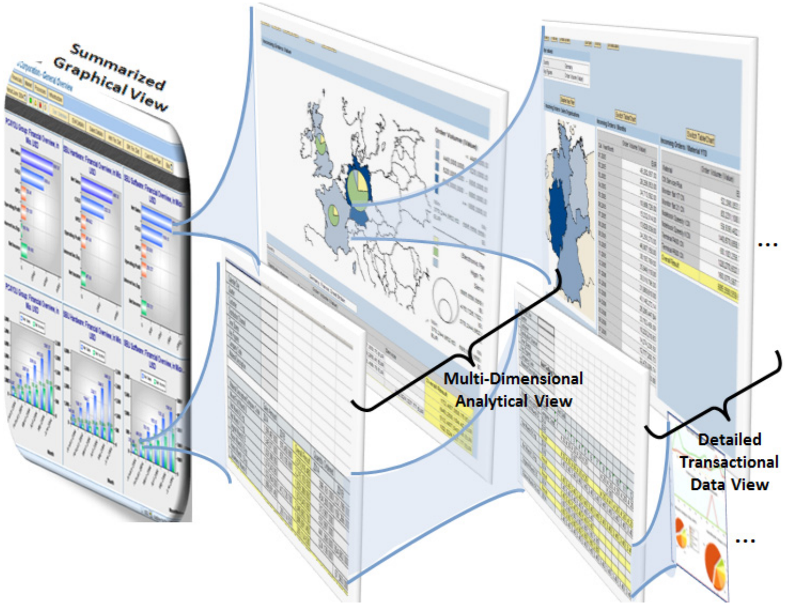

Fig. 1. Three Interconnected Information Layers in a Performance Dashboard

multilayered interactive visual display mechanism where its strategic support is built on the operational and tactical support provided. As illustrated in Fig. 1, in order to fully understand an item under strategic level support, one may need to drill into the tactical level or further into the operational level to fully understand the scenario. Hence, the quality of strategic support in a performance dashboard is influenced by the perceived usefulness of the operational and tactical support. As such, the following hypotheses are generated.

Hypothesis 3 (H_3): Quality of strategic support is influenced by the perceived usefulness of operational support.

Hypothesis 4 (H_4): Quality of strategic support is influenced by the perceived usefulness of tactical support.

Fig. 2 presents these four hypotheses in a research model.

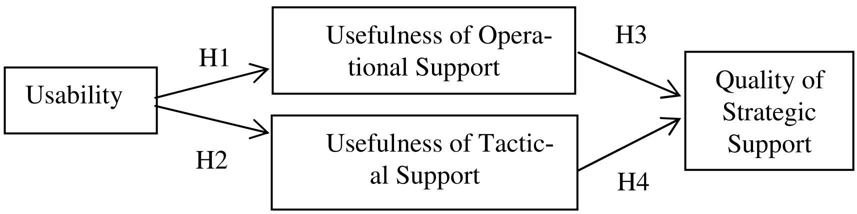

Fig. 2. Research Model

4 Methodology

A user-friendly and interactive performance dashboard prototype was developed to facilitate a Midwest university's quest for AACSB accreditation through efficient and effective organization, manipulation, access and display of pertinent data. Informal feedback was requested periodically from the managing faculty within the Department seeking accreditation, the AACSB mentor, and the AACSB visiting team throughout the dashboard development process. Additionally, the dashboard was presented at numerous faculty meetings and faculty members were invited to attend the dashboard planning meetings to learn more about the dashboard and provide their input. After ensuring that the most important functionalities are provided in the dashboard prototype, a formal survey will be deployed to gather feedback to test the proposed hypotheses.

A sample screenshot of the performance dashboard is presented in Fig. 3.

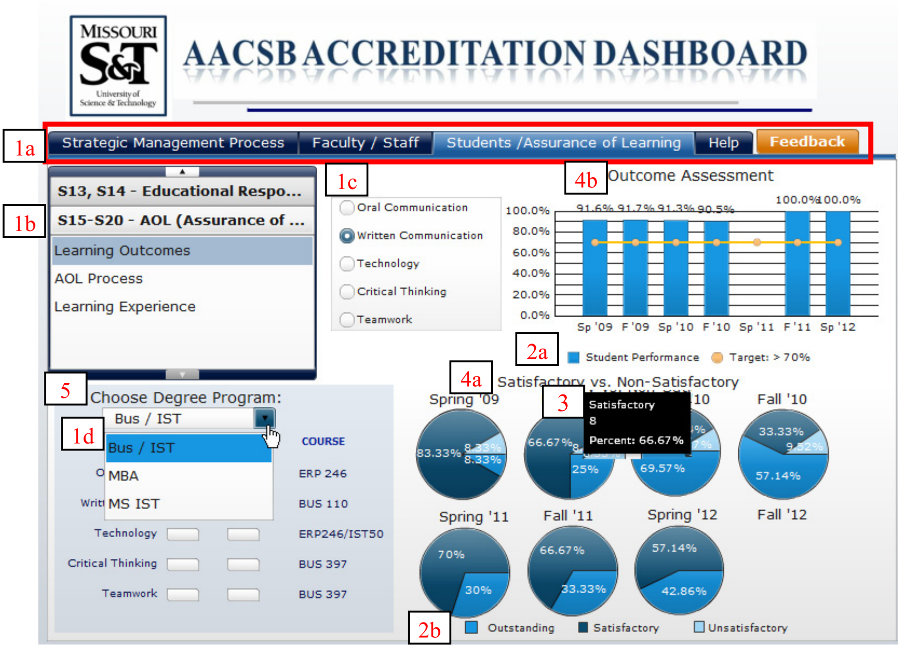

Fig. 3. Sample Screenshot of Performance Dashboard

User centric design principles were applied to ensure usability through ease of use, accessibility, learnability, and memorability. For example, information is categorize into different tabs, which are organized into a meaningful order and hierarchy as suggested by Marx et al (2011) and as shown in labels 1a, 1b, 1c, and 1d. A screen is typically divided into three or four sections to organize the information: a summarized and aggregated information section and two to three drill-down views to provide additional details based on user choices. Consistent layout design is maintained throughout all the tabs, making it easy for users to follow the design and to predict the effect of their actions. Color coding is used to represent the information content to make it easier for the user to understand the system and is kept consistent across different dashboard screens as shown in labels 2a and 2b in Fig. 3. Dynamic information tips are used when users move the cursor over an object to provide additional information or instruction of an object as shown in label 3 in Fig. 3. Common charts and diagrams are used to provide guided visual analysis (i.e., drill-down/drill across, slice and dice). Short and descriptive labels and explanations are provided for various information objects as shown in labels 4a and 4b in in Fig. 3. Clear information is provided where users must select an option to display the information pertaining to that option as shown in label 5 in Fig. 3.

5 Conclusions and Expected Contributions

A survey will be conducted and the results will be reported at the conference. We expect the proposed hypotheses to be supported, where the quality of strategic support is dependent on the usefulness of operational and tactical support provided by the performance dashboard. We also expect the usability of the performance dashboard to influence the perceived usefulness of the operational and tactical support provided by the dashboard.

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BookAidee: Managing Evacuees from Natural Disaster by RFID Tagged Library Books

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Abstract. BookAidee is a system to manage people who evacuate into public school buildings from disaster. The system identifies people by using already implemented structure of school library books that have RFID tags. These tags are used for connecting the person into the system database. We have implemented the system in server and client applications and tested the feasibility.

Keywords: Natural disaster, BookAidee, Evacuees, Library, RFID.

1 Introduction

The Great East Japan Earthquake occurred on 11th March 2011, caused following Tsunami and nuclear power plant accident. Due to this disaster, a huge number of people were evacuated from dangerous areas mainly to public safe buildings such as school gymnasiums. Up to 581 public schools accepted refugees for days or weeks [1]. In this sudden and confusing situation, it was difficult to manage information of people in the shelter. It is clear that some ID technology will help this kind of situation[2]. Besides, it is practical if the ID device is also useful in a time of peace.

For this purpose, we have implemented BookAidee system to manage people who evacuate into public school buildings from serious disaster. The system identifies people by using already implemented structure of school library books that have RFID tags inserted on their backs. When people check in the shelter, a library book is rented to each of them until they check out, as shown in Fig. 1. Book ID will be used to identify people when, for example, supplying foods, clothing and bedding. Distributing books at check-in can be smoothly done even during an electric power failure. The users can add and edit their personal information while they are in the evacuation building after the power resumes. School library books are exchangeable anytime, and some of them are expected to maintain peace of mind of evacuees, especially of nervous small children.

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 124–130, 2013.

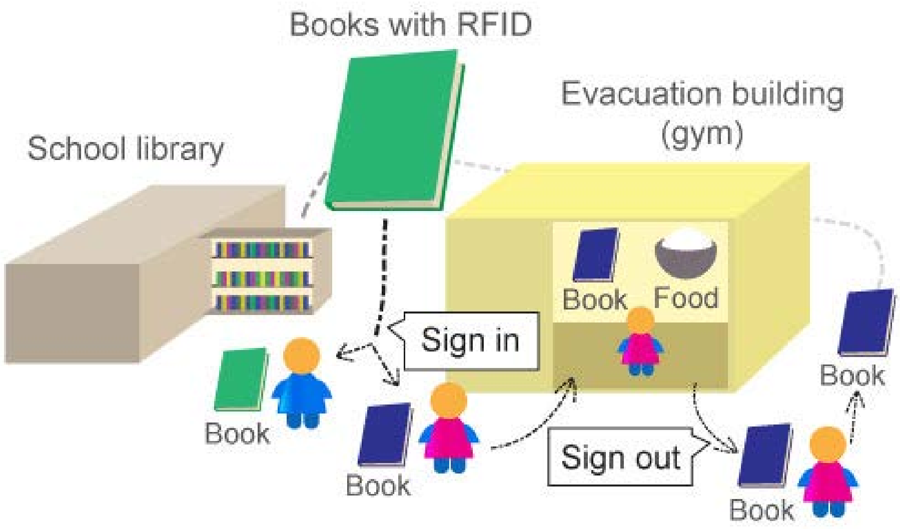

Fig. 1. Diagram of BookAidee system prototype

2 BookAidee System Prototype

The BookAidee application and the server prototypes are developed on notebook PCs to verify feasibility and mobility. The system is using Wi-Fi for communications between the client and server applications, as shown in Fig. 2. The hardware used in the prototype is easily deployed even in an emergency situation.

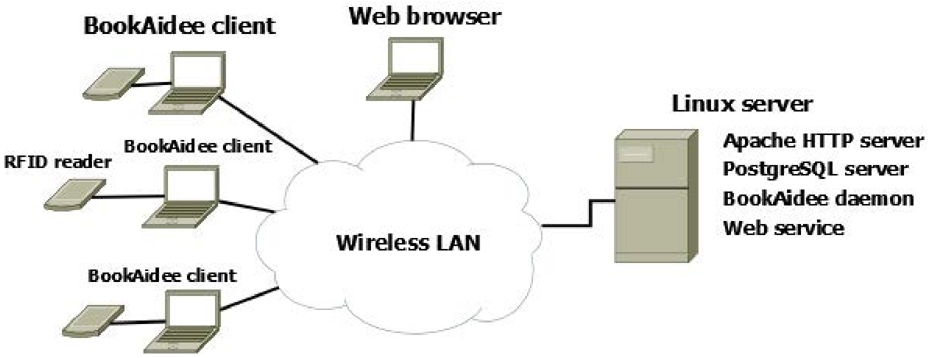

Fig. 2. Diagram of BookAidee system prototype

2.1 BookAidee Server

We have chosen Ubuntu distribution of the Linux operating system for the server, because it allows easy usage of open source projects and makes stable base for server usage. The server consists of following main components; PostgreSQL server, Apache HTTP server, Web API, Web service and BookAidee daemon. These components are listed in this chapter individuality for having a better understanding of systems internal working.

PostgreSQL Server. Database in the BookAidee system is responsible of storing information about the evacuees. When a new evacuee is registering into the system a personal ID is created. This personal ID is used to connect evacuee with the RFID tags ID and allows the interaction with the BookAidee system. The evacuee's personal information is also stored by using personal ID. This personal information includes name, address and age. It should be noted that giving the information is encouraged, but it is not mandatory for the evacuee. One of the reasons why evacuees are not forced to store any personal information is to avoid unnecessary queuing for the evacuees who are entering into the shelter. Accepting people to the shelter quickly has priority over registering personal information and the registration can be done anytime while people are staying in the shelter.

Apache HTTP Server. In the prototype system, client applications are not accessing PostgreSQL databases information directly. Instead of direct connection the Web API is implemented for this purpose. The HTTP server is also offering web service for accessing databases information by using basic web browser.

Web API. For having a layer of abstraction between client application and the database, a Web API called Wazapi was created for this project. The API is developed with PHP scripting language and its main responsibility is to receive commands from the client applications which are sent as POST requests over HTTP protocol. The response for the client application is sent in JSON format. As an practical example; if it is required to find person's ID which is linked to RFID tags ID. The client would send POST request with command getPersonId and as parameter the RFID tags unique ID. After receiving Wazapi would read this message and create a search for the database. Depending of the result of database search the Wazapi would return corresponding message about the database result.

Web Service. The web service is offering information for evacuees and administration. Information can be accessed by average browser in a form of website. The web service is allowing general people to search who has registered into the system and when. Password protected page allows the administrators to search more accurate information about the people who have entered their information into system: For example, who has accessed to the item supply.

BookAidee Daemon. This daemon notifies the server address to the client applications. It is running constantly in the server machine and answers to all UDP broadcasts which are coming from the clients. When a daemon receives a request from a client, it will be send response which has current IP address of the server machine. The main purpose of BookAidee daemon is to have a fast way of setting system up without having administrator configuring the network settings.

2.2 BookAidee Client Application

With the BookAidee client, our aim was to create an application which would be easy enough for an average person to launch and use. As an example, the system does not require user to insert IP address for the server machine. Instead the application is requesting this information from server's BookAidee daemon by utilizing UDP broadcasting. The BookAidee client was developed with Qt framework and C++ programming language. This allows the application to be ported under different operating systems without much work. Currently BookAidee client is supported under Microsoft Windows 7 and under Windows XP.

The following sequence diagram which is presented in Fig. 3, is visualizing the situation where user is accessing into the system for a first time by using RFID tagged book.

Presented in previous figure, the "Sign in" sequence is rather similar to the sequence other modes. Because of this it can be used as an example of client applications inner workings. Registering a evacuee into the BookAidee system can be simplified into five steps; The user places the book on the reader where it is handled by RFID Reader. Information from the tag is registered by a BAFeig

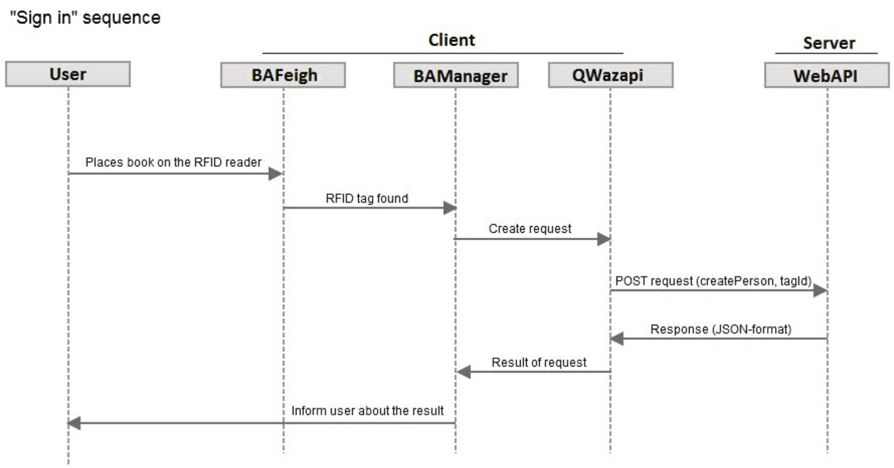

Fig. 3. Sign in sequence diagram

library which will pass it to BAManager. This manager will handle the readings depending of the mode that client application is using. After these steps the client application is requesting information from the Web API (Wazapi) by utilizing QWazapi library. The response is given back to BAManager which will handle it by giving information for the user.

RFID Reader. For reading the RFID tags from library books, we have chosen Feig electronics RFID Reader ISC.PR101-USB that works with frequency of 13.56 MHz. This device is matching with the devices that are used in libraries nowadays. The company is also supporting driver development on Linux and Windows operating systems, which is important for having a platform independent client application. Because the nature of RFID readers internal working, we created state machine which is running on separated thread. With this implementation, we could know when book has been placed or removed from the reader. It should be noted that our current prototypes client application has a requirement of being used under windows platform. The main reason for this is the missing development tools for Linux operating system, which we did not invest at the time of development.

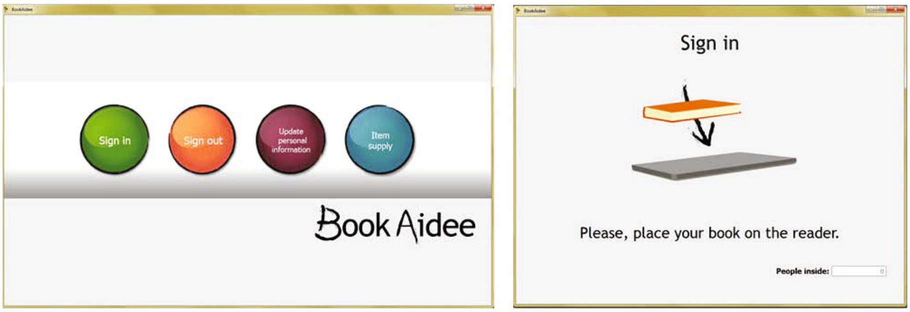

Fig. 4. BookAidee main interface and the sign in mode

2.3 User Interface

The main screen of the BookAidee application is simple and assumed to be easily approachable also in a stressful situation. With four big buttons for the main functionalities, the interface provides clear choices for the user, as shown in Fig. 4 (left). Our application is designed to have two types of users; the administrative staff managing the devices is able to access password protected functions and settings of the application, while regular users can interact with the application with the RFID tagged books.

Functionality. The four main functionalities of the application are referred as modes. In the "sign in" mode shown in Fig. 4 (right), the tags of the books are detected via RFID reader and logged into the database. The user interface shows the amount of books signed in so the number of people registered can be observed. In the "sign out" mode the books can be registered out from the system. The recorded actions of the user are kept in the database and the sign out time and date are saved. The sign in and sign out operations are independent and can be done at any time, so using the system doesn't have an effect on how fast people are taken into the refugee center. The staff and volunteers can hand the books over before the system is up and running, or during power shortage. In these kind of situation the signing in can be done later.

When a book is identified by the system, the system is recording the actions of the users into the database. The item supply mode can be used when supplies are provided for the people in the refugee center and in the update personal information mode can be used to save more detailed information about the current holder of the book. The switch books function inside this mode allows users to exchange books. Also sign in and sign out times and dates are saved.

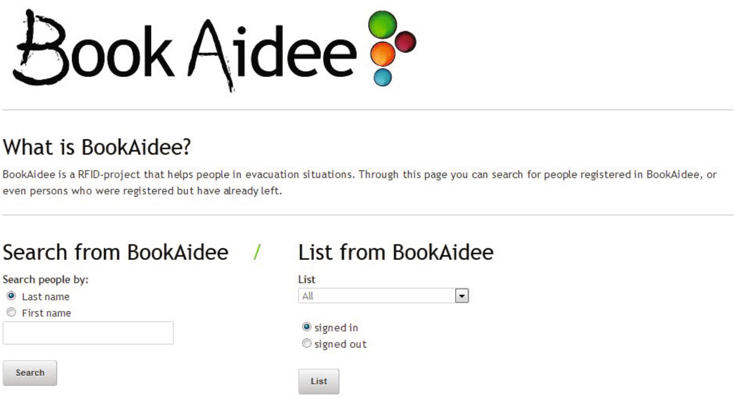

Fig. 5. Web application

Web Application. The bookAidee web application has access to the information recorded about the users. If the users have given data, for example their full name, in update personal information mode, it is possible to search them through the web application as shown in Fig. 5. Then it is possible to find out when this person has registered into the refugee center and if he/she is still in the center or already signed out. It is also possible to list all registered tags and the information recorded to them or sort the search by, for example, which tags have used the item supply mode. Currently the application registers only the timestamp of the tag reading in item supply mode and does not display the type of item given.

3 Conclusion

We have developed BookAidee system prototype, which in theory could be utilized in real life scenario to help refugees in the difficult times. The system prototype works as it is, but even the setup is relatively simple to build, many improvements are required before system can be put in actual use. As the BookAidee system is developed to be used by average users, most of the challenges with development locate in area of usability. For example, in some situations Ad Hoc network is not possible to be utilized and creating Wi-Fi network with actual hardware is required. For the average user this type of task might be overwhelming. The current prototype has features which should be improved. The item supply mode would need more development to be more functional. The system at its current state is capable of recording only the timestamp of a given item, not the type of the item. The administrators should be able to specify a type of item and the importance of it for better control of individuals in the refugee center. If the system would detect that some individuals haven't received important items such as food or medication, the administrative staff would get a notification to inspect the situation.

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Performance Monitoring of Industrial Plant Alarm Systems by Statistical Analysis of Plant Operation Data

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Abstract. Industrial plan alarm systems form an essential part of the operator interfaces for automatically monitoring plant state deviations and for attracting plant operators' attention to changes that require their intervention. To design effective plant alarm systems, it is essential to evaluate their performances. In this paper, some performance monitoring methods of plant alarms systems for alarm system rationalization are reviewed.

Keywords: Plant Alarm System, Nuisance Alarms, Plant Operation Data, Event Correlation Analysis.

1 Introduction

The advance of distributed control systems (DCSs) in the chemical industry has made it possible to install many alarms cheaply and easily. While most alarms help operators detect an abnormality and identify its cause, some are unnecessary. A poor alarm system might cause alarm floods and nuisance alarms, which reduces the ability of operators to cope with plant abnormalities because critical alarms are buried under a lot of unnecessary ones (EEMUA, 2007). Therefore, it is important to monitor and assess the overall performance of the alarm system continuously (ISA, 2009).

2 Key Performance Indicators of Plant Alarm System

Various types of key performance indicators (KPIs) are used for evaluating performance levels of an alarm system. EEMUA(2007) suggested some KPIs for alarm performance monitoring, such as average alarm rate, maximum alarm rate, and percentage of time alarm rates are outside of acceptability target.

The average alarm rate is calculated by total number of alarms annunciated to the operator / total number of time period. Recommended target for average alarm rate in steady operation is less than one per 10 minutes. The maximum alarm rate is the maximum number of alarms annunciated to the operator during any of the 10 minutes time slice. Rates approaching 10 alarms in 10 minutes is not reliably sustainable by an

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 131–135, 2013.

operator for long periods. Percentages of time alarm rates are outside is useful for showing improvement made to an alarm system during alarm rationalization.

The “top-ten worst alarm method” has been widely used in the Japanese chemical industry to reduce the number of unnecessary alarms. It is used to collect data from the event logs of alarms during operation, and it creates a list of frequently generated alarms.

Although this method can effectively reduce the number of alarms triggered at an early stage, it is less effective at reducing them as the proportion of the worst ten alarms decreases. Because the ratio of each alarm in the top-ten worst alarm list is very small in the latter case, effectively further reducing the number of unnecessary alarms becomes difficult.

3 Event Correlation Analysis of Plant Operation Log Data

Nishiguchi and Takai (2010) proposed a method for data-based evaluation that referred to not only alarm event data but also operation event data in the operation data of plants. The operation data recorded in DCS consist of the times of occurrences and the tag names of alarms or operations as listed in Table 1, which we call “events” hereinafter.

Table 1. Example of operation data

Date/Time	Event	Type
2011/01/01 00:08:53	Event 1	Alarm
2011/01/01 00:09:36	Event 2	Operation
2011/01/01 00:11:42	Event 3	Alarm
2011/01/01 00:25:52	Event 1	Alarm
2011/01/01 00:30:34	Event 2	Operation

The operation data are converted into sequential event data $s_i(k)$. When event i occurs between $(k\text{-}1)\Delta t$ and $k\Delta t$, $s_i(k) = 1$, otherwise $s_i(k) = 0$. Here, Δt is the time-window size and k denotes the discrete time. The cross correlation function, $c_{ij}(m)$, between $s_i(k)$ and $s_j(k)$ for time lag m is calculated with Eq. (1). Here, K is the maximum time period for lag and T is the time period for complete operation data.

$$c_{ij}(m)=\begin{cases}\sum_{k=1}^{T/\Delta t-m} s_i(k)s_j(k+m) & (0\le m\le K/\Delta t)\\ c_{ji}(-m) & (-K/\Delta t\le m<0)\end{cases} \tag{1}$$

When two events, *i* and *j*, are independent of each other, the total probability that two events will occur simultaneously more than c_{ij}^* times, which is the maximum value of the cross correlation function with time lag m is given by Eq. (2), where λ is the expected value of c_{ij}.

$$P(c_{ij}(m)\ge c_{ij}^*\,|-K/\Delta t\le m\le K/\Delta t)\cong 1-\left(\sum_{l=0}^{c_{ij}^*-1}\frac{e^{-\lambda}\lambda^l}{l!}\right)^{2K+1} \tag{2}$$

Finally, the similarity, S_{ij}, between two events, *i* and *j*, is calculated with Eq. (3) (Nishiguchi and Takai, 2010).

$$S_{ij}=1-P(c_{ij}(m)\ge c_{ij}^*\,|-K/\Delta t\le m\le K/\Delta t) \tag{3}$$

A larger similarity means a stronger dependence or closer relationship between the two events. After similarities are calculated between all combinations of any two events in the plant log data, all events are classified into groups with a hierarchical method for clustering.

The following four types of nuisance alarms and operations can be found by analyzing the results obtained from clustering.

1. Sequential alarms: These are when a group contains multiple alarm events that occur sequentially. Changing the alarm settings of sequential alarms may effectively reduce the number of times they occur.
2. Routine operations: These can be when a group includes many operation events and operation events in the same group appear frequently in the event log data. These operation events can be reduced by automating routine operations using a programmable logic controller.
3. Alarms without corresponding operations: These can be when a group contains only alarm events and operation events are not included in the same group. As every alarm should have a defined response, these may be unnecessary and should be eliminated.
4. Alarms caused by operation: Operations can cause alarm events to occur after all operation events in a group. These are unnecessary because they are not meaningful or actionable.

4 Alarm System Evaluation of Ethylene Plant

Idemitsu Kosan Co. Ltd. started operations at the ethylene plant of their Chiba complex in 1985. The plant log data gathered in one month included 914 types of alarm events and 857 types of operation events, and a total of 51640 events was generated. Figure 1 shows the points at which 1771 types of alarm and operation events occurred.

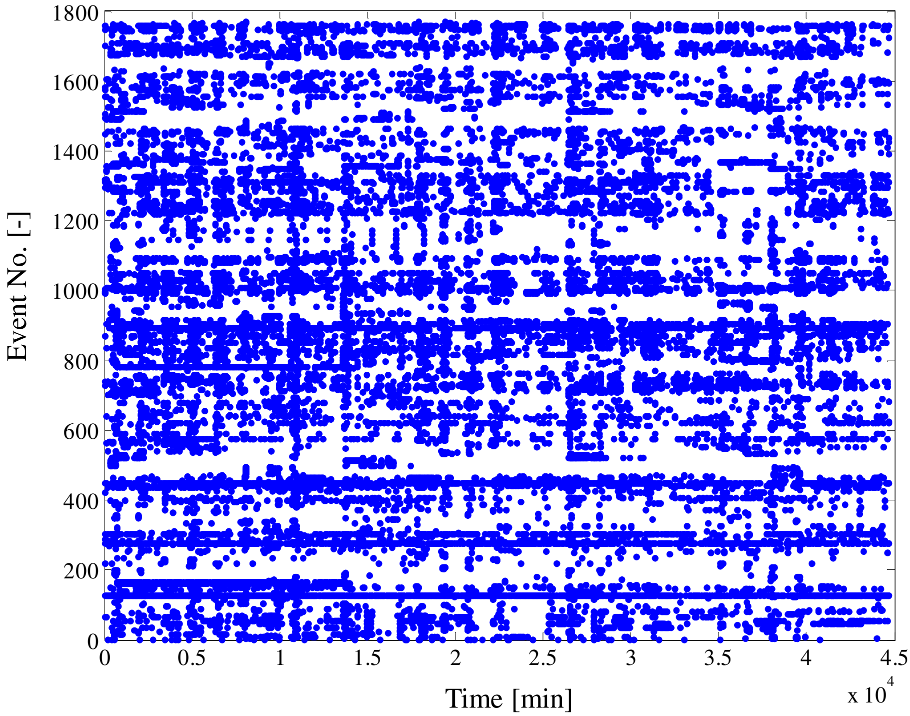

Fig. 1. Operation data of ethylene plant (Noda *et al.*, 2012)

Event correlation analysis was applied to the operation data obtained from the ethylene plant (Noda *et al.*, 2012). By using the hierarchical method of clustering, 1771 types of alarms and operation events were classified into 588 groups. Figure 2 is a similarity color map of events in the top 10 worst groups, where the alarm and operation events are ordered in accordance with the group Nos. The red indicates that two events have a high degree of similarity.

The top group contains five types of alarm events and ten types of operation events, and the total number of events in the group accounted for 5.8% of all generated events at the ethylene plant. Although the total number of events in the worst 10 groups accounted for 32.4% of all generated events at the plant, this included only 4.2% of alarm and operation event types.

Evaluation results showed that the method could effectively identify unnecessary alarms and operations within a large amount of event data, which should be helpful for reducing the number of unnecessary alarms and operations in other industrial chemical plants.

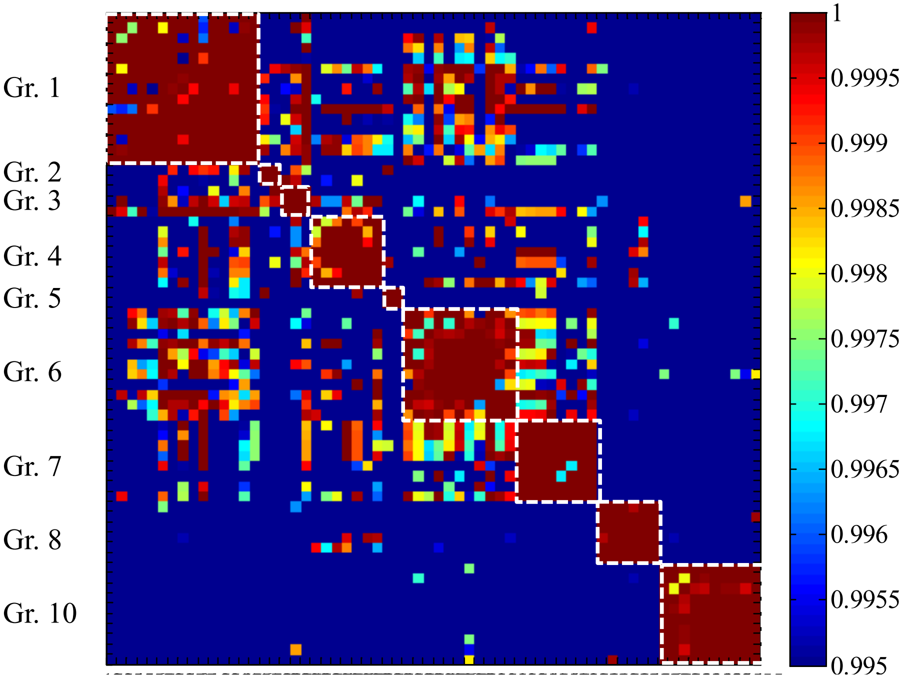

Fig. 2. Similarity color map (Noda *et al.*, 2012)

5 Conclusions

This paper reviewed quantitative evaluation methods for plant alarm systems based on plant operation data to rationalize plant alarm systems. Monitoring and assessment of performance of the plant alarm system may trigger maintenance work or identify the need for changes to the alarm system.

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Pre-study Walkthrough with a Commercial Pilot for a Preliminary Single Pilot Operations Experiment

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Abstract. The number of crew members in commercial flights has decreased to two members, down from the five-member crew required 50 years ago. One question of interest is whether the crew should be reduced to one pilot. In order to determine the critical factors involved in safely transitioning to a single pilot, research must examine whether any performance deficits arise with the loss of a crew member. With a concrete understanding of the cognitive and behavioral role of a co-pilot, aeronautical technologies and procedures can be developed that make up for the removal of the second aircrew member. The current project describes a pre-study walkthrough process that can be used to help in the development of scenarios for testing future concepts and technologies for single pilot operations. Qualitative information regarding the tasks performed by the pilots can be extracted with this technique and adapted for future investigations of single pilot operations.

1 Introduction

Technology is currently available that assists pilots with take-off and landing, parking at airport terminals, en-route navigation, and various other operations. Many other forms of advanced technologies and concepts of operations are currently being developed and evaluated for possible implementation over the next few decades [1]. Within the Next Generation Air Transportation (NextGen) system [2], it is assumed that the adoption of advanced aeronautics technologies will alter the role and responsibilities of the operators in the system. This paper will focus on one potential change to flight deck operations, called single pilot operations (SPO), which is not presently envisioned in the NextGen initiatives.

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 136–142, 2013.

Fifty years ago, flight decks had up to a five person crew, a number that has steadily decreased over time. Currently, commercial aircraft have two flight deck crew members: a captain and a co-pilot. Either the captain or the co-pilot may perform the duties of pilot flying (PF) and pilot monitoring (PM). According to Hutchins [3], the pilot flying is concerned with controlling the aircraft, while the pilot not flying (or pilot monitoring) communicates with air traffic controllers (ATCos), operates aircraft systems, accomplishes checklists, and attends to other duties in the cockpit. While the captain always retains command and leadership of the flight, the duties of PF and PM typically are traded back and forth from one leg to the next leg. In order to successfully reduce the number of crew members from two to one for single pilot operations (SPO), the tasks of one pilot must be transferred to automated systems or otherwise replaced.

The benefits of transferring tasks to automation have been demonstrated in the past. Automation typically lowers operators' overall workload [4], and in mundane conditions, automation can maintain more consistent and accurate performance than that obtained by human operators. However, the drawbacks of automation are well documented. Automation leads to operators to becoming complacent [5], and to "out-of-the-loop" syndrome, which can cause a decrease in operator situation awareness [6]. "Out-of-the loop" syndrome occurs when an operator is less involved in and therefore less aware of the state of a system. The reduction in operator involvement is usually a result of more advanced technology that performs actions in place of the operator. Moreover, the modern cockpit is already highly automated. Pilots now supervise and monitor aircraft systems and automation tools [7]. To increase the level of automation that is required for single pilot operations would mean that the pilot's role will evolve more towards the title of 'flight manager' than actual 'flyer' of an aircraft. Thus, the benefits and costs associated with SPO must be evaluated.

The major benefit of SPO is probably reduced cost of operations through reduction of crew costs (i.e. one less pilot to pay per flight). In addition, Norman [8] proposes that the benefits of SPO would include more efficient crew scheduling and better aircraft availability. Also, with one less crew member, the size of the cockpit could be reduced, leading to lighter aircraft. Moving to SPO is also practical because current regulations specify that all aircraft must be capable of being operated by one pilot from either seat. This means that much of the infrastructure already exists for SPO [7] for commercial flight. For general aviation, the concept of a single pilot is not new, so air traffic controllers already have experience interacting with single pilot flight decks.

The main question of interest in any move to SPO is "what is being lost when transitioning from a two-pilot crew to a single pilot?" According to Harris [7], de-crewing has not affected flight safety when paired with appropriate technology available on a flight deck. Therefore, it is expected that automation will be an important aspect of SPO. But to adequately answer "what is lost", and therefore what needs to be made up for with automation or other procedures, research must aim to fully understand the perceptual, cognitive, and social aspects of current, dual-crew flight operations. With a more complete knowledge of the factors that drive pilot and co-pilot interactions, SPO flight decks can be designed to ensure that SPO will achieve safe and efficient flight operations. Factors involved in crew resource management (CRM) such as operator decision making, adaptability, communication, situation awareness, workload, and expertise, among others, must be understood to develop automation tools and flight deck procedures that will accommodate the loss of the second crew member on the flight deck. The goal of the present study is to illustrate the use of using a pre-study walkthrough of a pilot task to gather the information about the flight deck processes and interactions occurring during dual-crew operations. Findings from such a walkthrough would allow researchers to create a generic task flow. This task flow, in turn, can serve as a basic template for designing experimental flight scenarios to be used in simulation evaluations of SPO concepts and technologies. In the following sections we describe how, for one pilot (among several which we examined), we used a pre-study walkthrough to uncover issues and problems that should be addressed in evaluating SPO. It is not our purpose in this report to propose solutions for these issues. Also, the ultimate simulation evaluations that grew out of this process are not described here, but will be reported in later publications.

2 Method

2.1 Participant

Commercial pilots served as subject matter experts (SMEs) for the pre-study walkthroughs. The process for one of these pilots is described below.

2.2 Apparatus

A generic flight scenario was drafted in Microsoft PowerPoint with an arrival path illustrating a descent into Denver International Airport (DEN) (Figure 1). The placement of weather cells in the scenario was intended to interfere with nominal procedures associated with flying the arrival route. This scenario was used to guide the walkthrough along with a semi-structured interview that was developed to guide the pilot through the flight scenario. Fig. 2 includes sample questions that were used in the interview. The questions were selected to elicit detailed information regarding the communication, cognitive decision making, and physical actions that the pilot would experience during the flight. In particular, the pilot was questioned about his goals during a typical flight, the time pressure present, errors that he might expect to occur, his decision process, and from what displays he would expect to retrieve specific information in the cockpit.

A laptop computer using Camtasia Studio was used to record the interview as the pilot performed the walkthrough. Camtasia Studio is an audio/video recording and editing software. Audio input was received from a microphone built into the laptop. Recordings were reviewed and any information that was overlooked during the live walkthrough was noted.

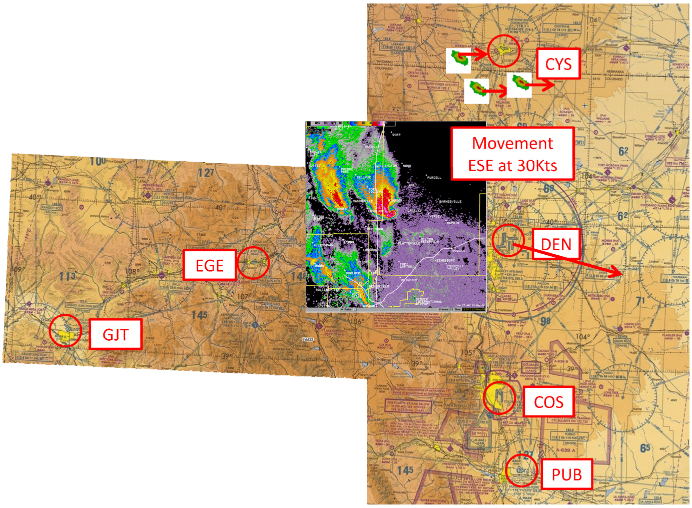

Fig. 1. The generic flight scenario generated in Microsoft PowerPoint. A convective weather cell headed SE towards DEN. The pilot attempted to fly in to DEN from the Northeast. A color version of the figure is available in the electronic copy of this paper.

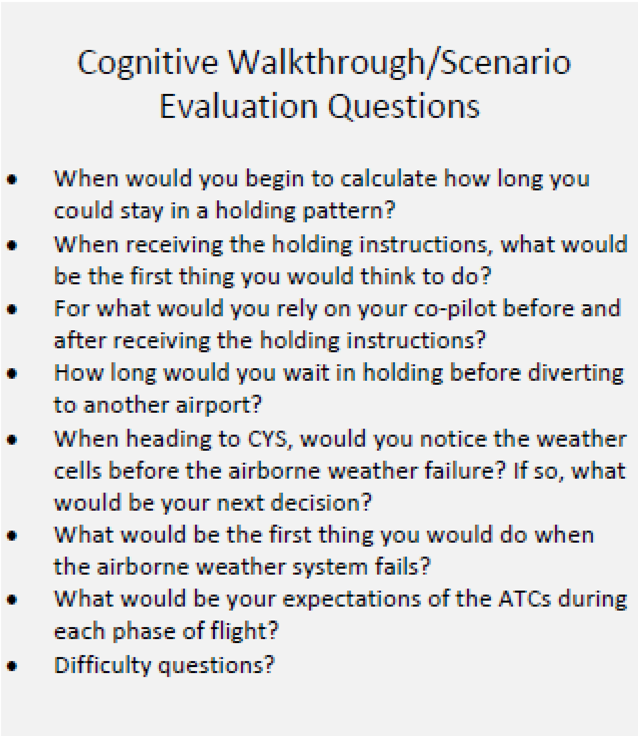

Fig. 2. Examples of questions that the pilot was asked. These questions were designed to extract cognitive decision making, communication, and timing information from the pilot.

2.3 Procedure

The pilot arrived at the test area and was given a brief introduction to the study. The researchers explained what types of questions would be asked (questions related to cognitive, behavioral, and communicative decision making). Using the PowerPoint scenario described above, the pilot was asked to imagine that he was flying into Denver International Airport. He was told that he was at the top of descent point, planned to perform the arrival procedure, and then planned to land at the airport. Subsequently, the pilot was told that air traffic control issued a warning that holding might be expected during the arrival. The pilot was then given instructions to initiate a holding pattern due to potential weather disruption at the airport. The aircraft had enough fuel to enter the holding pattern for 5 minutes. Once 5 minutes passed, the pilot had to make a decision to fly to another airport if he could not land at the Denver airport.

The generic scenario described above was then walked through, step-by-step and with no interruptions, by the pilot. The pilot performed a think aloud protocol, describing his actions, thoughts, behaviors, and potential communication that would occur between him and a co-pilot, and/or between him and an air traffic controller. The pilot was asked to tell a story of the potential flight from beginning to end with as much detail as possible. After the first walkthrough of the scenario, the researchers took the pilot back through the scenario again, asking numerous pre-determined questions relating to his prior responses, as well as follow-up questions to clarify any concerns.

During and after the walkthrough process, the researchers took notes on a printout of the PowerPoint scenario slides, and provided alternative indicators in the scenario to improve its usefulness in future studies. Improvements in the scenario design were changes that would make the scenario more realistic while still requiring actions to be made by the pilot that would reflect critical underlying factors that would influence the pilot's decision making, communication, and behaviors. In terms of SPO, it was essential to obtain all information that reflected pilot and co-pilot decision making, communication, and interactions. This information was intended to be of use in future investigations of concepts of operations involving remote crew members or automated systems that would take over the co-pilot's role.

3 Data Collection

The information gathered was qualitative, retrieved from a think aloud protocol and semi-structured interview questions captured during the walkthrough. Results were organized and summarized using flow charts designed in Microsoft Visio (see Figure 3). From the information and insights gathered from the pre-study walkthrough, a prototypical scenario and flowchart of events were created. These two items provided a basic template for future SPO experimental scenario development.

3.1 Prototype Scenario

The generic scenario created after the cognitive walkthrough takes pilots on an arrival path to Denver International airport. At a specific time during descent, the pilot was asked to enter into a holding pattern due to weather complications at Denver. The pilot has limited fuel, enough for 5 minutes in the holding pattern. After this critical time period, the pilot must make a decision to divert safely to one of a few nearby airports. The scenario exercises the communications that would be involved between the pilot and his/her co-pilot, communication between the pilot and air traffic control, the mental computations require for determining how long to stay in the holding pattern, and the time-sensitive decision-making points involved in determining an alternative airport and route to that airport

3.2 Temporal Flow Chart

Events during which potential verbal and nonverbal communication between the pilot and co-pilot were identified. The events that required communication between the pilot and co-pilot were flagged as critical events that should be evaluated during the subsequent SPO experiments. Events requiring decision-making (or giving insights into pilot decision-making) were also identified and flagged. Fig. 3 provides an illustration of the scenario, with the critical communication slot between a pilot and co-pilot during a holding pattern flagged in red (bottom left box of Figure 3).

Fig. 3. Snippet of a flowchart of the prototype scenario that was generated after the cognitive walkthrough. The red box (bottom box on the left) flagged a critical communication slot that should occur between a pilot and co-pilot during a holding pattern. During single pilot operations experimentation, this time slot will need to be closely examined. A color version of the figure is available in the electronic copy of this paper.

4 Discussion

This example case illustrates how findings from a pre-study walkthrough could be used to assist the development of scenarios for SPO investigations. Although this paper only provided one example case, it is recommended that cognitive walkthroughs of this type be performed for a variety of scenarios to form a database of template scenarios that can be used in future evaluations of SPO concepts of operations and/or in the evaluation of alternative displays and technologies designed to support SPO. The detailed knowledge of when to look for critical decision-making points, and where essential communication between pilots are likely to occur, should help researchers to better design SPO experiments to test specific concepts and technologies. Researchers can also use this information to pinpoint when errors, faulty decision-making, and poor communication may arise during SPO.

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Migration Tolerant Human Computer Interaction for Air Traffic Controllers

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Abstract. Human machine interfaces (HMI) in the product division of air traffic management (ATM) are in use for long time spans. For an efficient use of HMIs not only user centered but also migration tolerant designs are important. Migration tolerance therefore means considering future requirements for a long lasting controller HMI life cycle. For efficient ATM, the concept of system wide information management (SWIM) will be introduced. This generates a large amount of additional information that will influence controller work. In this paper, we therefore describe a new controller role called Information-and-Conflict-Manager (ICM) who handles the complexity induced by SWIM. The resulting HMI design draft demonstrates how the integration of data could be managed. ICM also supervises training to support controllers successfully passing future flight guidance transitions.

Keywords: air traffic control, flight guidance, human machine interaction, migration tolerance, system wide information management, transition steps

1 Introduction

The global air traffic is expected to constantly grow, which is also predicted for the future in a range of 1.6 to 3.9 % [1]. In order to cope with this, several challenges like capacity bottlenecks or environmental aspects have to be managed. On the one hand hardware development, i.e. new aircraft avionics and propulsion technologies provide some of the necessary benefits. On the other hand software and methodological solutions are essential to cope with new requirements of future air traffic control, in particular new HMI solutions and flight guidance approaches. As a main actor, air traffic controllers have to be supported in their work. The working environment of air traffic controllers described in chapter 2 encompasses a general radar screen, flight strips, radio telephony and other information tools like weather or aircraft performance data displays. Besides flight strips, the controllers' decisions predominantly are based upon information on the radar screen. In the air traffic controller domain conventional HMIs have life cycles of around 20 years. Work environmental improvements are hardly integrated in terms of HMI updates or enhancements.

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 143–152, 2013.

In contrast to new designs in the field of consumer electronics, which appear annually, as for example the smartphone HMIs, the design approach in ATM has to be long-term. Moreover the specifications of ATM research programs, a mix of different capabilities in the aircraft fleet and new information sources require an HMI design tolerant against technological changes and different controller working paradigms.

The research aim of improving ATM processes nowadays is linked with more detailed information about all stakeholders and a more individual planning for all aircraft flights. In the ATM context the system wide information management (SWIM) concept will be introduced, which delivers a variety of data from many different sources building the base of better planning facilities [2]. Indeed better planning is possible but more complex for the responsible planner or controller. Therefore a new working position in allusion to the multi-sector planner [3], [4] called Information-and-Conflict-Manager (ICM) [5] is designed. He monitors incoming information from the SWIM network and forwards only the task-relevant information to the corresponding planner and tactical controller. Additionally he coordinates flight guidance decisions and supervises the training of operational controllers while on duty. The HMI-based training helps controllers to become familiar with the new flight guidance steps (see chapter 2). In conclusion new HMI solutions have to be developed to guarantee communication and coordination between different types of controllers and automation on ground and on board. These interfaces have to come along with small adaptions to the needs of the current guidance step with respect to information, automation and user-centered capabilities [6], [7]. The changing tasks of the controller then can be carried out with the corresponding data of the SWIM network (chapter 3.2) and hence build a basis for a more efficient ATM process.

In section 2 we shortly describe the status quo of controller working positions in air traffic control and their corresponding HMIs. Additionally we highlight the current distance based method of flight guidance and the envisaged transitions towards time based, trajectory based and finally performance based guidance. Section 3 depicts our basic assumptions and requirements for the future air traffic control (ATC) environment and reveals key SWIM elements, which fundamentally contribute to our HMI prototype introduced in chapter 4. Based on requirements for a future ATC environment we will illustrate our concept of an Information-and-Conflict-Manager position and introduce an HMI design layout. Besides that we will also demonstrate the possible HMI solutions of transitions from flight guidance step 1 to another. Section 5 summarizes and concludes our paper.

2 Background of Air Traffic Management

Arriving and departing air traffic has to be guided through the terminal maneuvering area (TMA) close to an airport by the responsible air traffic controller. Predefined standard arrival routes and departure routes are used to guide aircraft safely and without collisions. The controller has to ensure safe air traffic from the departure until the arrival. There are different working positions for controllers in the whole ATM process. The en-route controller guides aircraft between airports in large altitudes.

The arrival, departure and tower controllers handle aircraft in their specific start and end phase or responsibility region. These tactical controllers act more operational than the strategically planner. The conventional flight guidance approach is distance based. To guarantee safety, several rules of the International Civil Aviation Organization (ICAO) have to be followed. The correct separation between different aircraft of e.g. three nautical miles depends on rules in a wake vortex matrix. The controller therefore advises specific flight maneuvers to the pilots. To create more efficient air traffic and enhance existing management, the Single European Sky ATM Research Programme (SESAR) and the US-American project Next Generation Air Traffic Management (NextGen) were founded. The individuality and capabilities of each stakeholder in particular airlines, airports or controller organizations shall be taken more into account for generating improved benefit. Due to SESAR three further flight guidance approach steps will be implemented until a time horizon of 2020. The guidance approach shall be shifted first to a time based (step 1), second to a trajectory based (step 2) and third to a performance based approach (step 3) [8], [9].

Distance based separations between aircraft are used to avoid flights through wake vortexes of other aircraft. But wake vortexes collapse in a certain time not at a certain distance. Hence, in specific wind situations time separation between aircraft would increase capacity. Negotiated times at significant waypoints like runway thresholds or metering fixes become more important. The ground and airborne systems or operators negotiate a certain target time for every waypoint, which at its best ensures collision and wake vortex avoidance with other aircraft at these points. The separation is still important, but the controller can concentrate more on adhering times including separated traffic. Aircraft can fly a more preferred profile as long as negotiated times are kept. Actual HMIs hardly support time based air traffic management. The second step of a trajectory based approach consists of latitudinal, longitudinal, altitudinal and time-related values for every single regular spaced point on the way from an aircraft's actual position to its destination. Beyond negotiated times at significant waypoints, times and other parameter are important at many waypoints on their trajectory. The task of conformance monitoring therefore becomes more important to supervise all aircraft flying along calculated trajectories. This implicitly shall ensure minimal separations and times at significant waypoints. The last step to a performance based flight guidance approach takes into account performance parameter like carbon dioxide emission, kerosene consumption, noise emission and direct operating costs. These aspects are very difficult to handle with current controller HMIs. Furthermore the optima for one aircraft and for the whole air traffic may differ at a certain time. The support by an automated system becomes most important in this step. Separation, negotiated times, trajectories and the environmental and economic parameters have to be supervised. The electronic decision support system should calculate the best options and suggest them to the controller via HMI. The DLR-projects Future Air Ground Integration and flexiGuide have shown some challenges even if reaching step 1 [10] and the need of automation support. Concluding new HMI solutions and especially transitions between HMI evolution states shall support controller work according to the future requirements and methodologies. Additionally a shift of controller working responsibilities can help to alleviate the amount of workload.

3 Requirements of Future Air Traffic Control

This chapter describes basic assumptions for the ATM future and depicts the most important requirements of the system wide information management (SWIM) concept. Based on these requirements we will propose our controller roles and interaction with HMIs.

3.1 Scenario Assumptions

Some basic assumptions connected to future development were made to legitimate the following controller and HMI solutions:

- With the growth of world-spanning high-speed telecommunication networks vast data provision and data exchange will be less challenging
- Exact position and navigation surveillance will be delivered
- Communication between controllers and pilots via data link is the predominant way of contact
- There will still be a mix of traffic with aircraft having different equipment degrees like anterior avionics characteristics and capabilities
- All SWIM stakeholders provide their information relevant for others into the network

3.2 System Wide Information Management

As described in [2] the concept of SWIM aims at a change in paradigm of how information is managed and spread along the whole (European) ATM system. The implementation of the SWIM concept supports the provision of commonly understood quality information delivered to the ATM stakeholders and therefore spans a great portfolio of information. Although the ATM System covers numerous stakeholders our work will mainly focus on the information supply and exchange between Air Traffic Control and air-side, i.e. approach control and aircraft operators. Given the complex nature of SWIM, which is to go across all ATM systems, data domains, business trajectory phases and the wide range of ATM stakeholders, it is not expected that one solution will fit all. So will neither our solution cover an overall data provision, but it will contribute to a more efficient usage of available data in order to reach the aimed steps of flight guidance (SESAR step 1 to step 3) as described in chapter 2. We expect that SWIM therefore will be a key enabler for the future SESAR systems and help to fulfill the envisaged goals as for instance efficiency, optimization of capacity, environmental friendliness and saving economic costs.

In the SESAR work plan, the SWIM concept aims at a paradigm shift from mere message exchange to information publishing, using and contributing, meaning all ATM actors share their information and this requires a more precise and more dynamic way of work [2]. For the realization of our model we propose to take advantage of assumed network technologies in order to enable an efficient information exchange of ATC and aircraft crews resp. airline operation centers.

For the provision of high-quality and timely information, the so called network operations plan (NOP) of the SWIM concept might be a key tool [12]. The NOP is the central flow management unit web interface for system to system interoperability and has two main benefits. On the one hand it helps monitoring the real-time status of the airspace, the air traffic, its flow and capacity management measures. On the other hand it also supports planning of flight operations in a collaborative way from the strategic to the tactical phases, hence optimizing the use of available ATM capacity. Currently targeted stakeholders are air traffic system reporting offices, aircraft operating centers and flight plan service providers, but we will address the SWIM concept to the air navigation service providers (ANSP) world as well. As mentioned above several data sources are needed for the ANSP in order to serve the flight on several levels such as [13]:

- *Flight information* – the detailed route of the aircraft defined in four dimensions (4D), so that the position of the aircraft is also defined with respect to the time component
- *Aeronautical information* – resulting from the assembly, analysis and formatting of aeronautical data
- *Meteorological information* – on the past, current and future state of earth's atmosphere relevant for air traffic
- *Environmental information* – about carbon dioxide and kerosene consumption regarding different flight options, and flight areas affected by noise emissions
- *Aerodrome Operations information* – the status of different aspects of the airport, including approaches, runways, taxiways, gate and aircraft turn-around information
- *Capacity and Demand* – information on the airspace users' needs of services, access to airspace and airports and the aircraft already using it
- *Flow* – the network management information necessary to understand the overall air traffic and air traffic services situation
- *Surveillance* – positioning information from radar, satellite navigation systems, Automatic Dependent Surveillance - Broadcast, aircraft data links, etc.

Not all information needs to be displayed to everyone at any given point of time. The most important data in order to decide quickly and safely have to be shown to the right controller at the right time in the right form with the right workload. Therefore a new controller role will fit this requirement as described in the next chapter.

4 User-Centered Controller and HMI Design

An air traffic controllers' working domain has special requirements to guarantee the safe execution of their tasks. This has to be considered when designing an HMI for ATC. The described future requirements have to be handled in future controller working environments. Also in our case the Information-and-Conflict-Manager who manages the information stream of the SWIM network will require a new HMI solution and therefore a new interaction scheme between ICM, controllers and automation.

4.1 New Controller Role Information-and-Conflict-Manager

According to the SWIM concept our approach targets the visualization of SWIM related data obtained by a system-to-system internet communication and the introduction of the Information-and-Conflict-Manager Working (ICM) position. This will be extended in accordance to the flight guidance transition steps (see chapter 2).

The ICM working position is supposed to bridge the data flow between the incoming data sources and the different air traffic controller (ATCO) positions. Besides that, the ICM will handle the traffic on a strategic level. In accordance to new operator roles as proposed in SESAR concepts of operations our ICM embodies in parts the role of the multi-sector-planner (MSP) concept and the dispatcher [11]. The MSP coordinates multiple conventional sectors and plans medium-term aircraft trajectories in his area of responsibility. The balancing of workload for safe flight guidance of all individual sector controllers shall also be guaranteed by the MSP [3]. Similar to the ATCO role of an MSP as proposed in SESAR, the dispatcher role is described [11]. Within this operational concept the dispatcher monitors the traffic in a given airspace, and when a critical event pops up, notified by the system, he/she tries to solve it directly or delegate it to an expert. An expert would be comparable to a tactical controller. The dispatcher therefore is also in charge of managing his/her own workload as well as the workload of the experts by delegating the problems to ATCOs. The dispatcher has a global awareness of the problems and their resolution.

The new operator role represented by the ICM shares both aspects of the MSP and the dispatcher ATCO role but goes a step beyond. He not only manages the strategically planning and conflict resolution of traffic but operates also as a trainer-on-the-job and as an information distributor to the tactical controllers without contacting pilots or making direct operational air traffic management decisions. Complexity is induced by the SWIM network, 4D trajectory management and most important the HMI transitions from step 1 to step 3. Therefore the ICM scans these data and relieves the operational controllers by only forwarding the tactical relevant information. Due to the ICM tasks an HMI for the described requirements is necessary.

Fig. 1 demonstrates a suggestion of a possible prototype of the ICM working position. The concept of the ICM working position proposes an at least 50” display, which is big enough to encompass the several displays at the bottom and the general radar screen as depicted in Fig. 1. The general radar screen displays the overall traffic situation of all supervised tactical controllers within their sector and the universal time coordinated (UTC) in the lower right corner. The radar screen can be used as one integrated display for the available data according to a specific flight. The displays in the bottom bar deliver very different ICM options. If new data concerning one of the nine displays arrives, the corresponding option will be marked. So every incoming data can be noticed. The bottom bar shows SWIM information in all nine displays. The first six displays supplementary allow for communication with stakeholders.

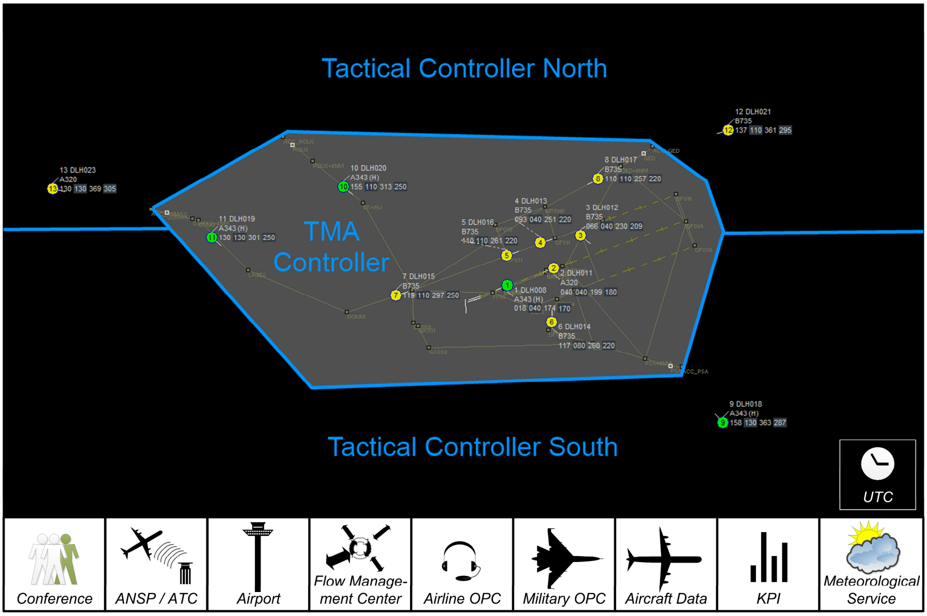

Fig. 1. Display Draft for Information-and-Conflict-Manager Position

The Conference monitor on the outer left enables the communication with the supervised controllers. When selecting an operator position, the ICM awaits a response of the controller. In case of a positive response, the ICM initiates the communication with the corresponding controller via headset. In addition to that, the ICM accesses the controller's radar screen remotely. However, the ICM is not permitted to actively guide the aircraft of the contacted controller.

The ANSP/ATC monitor shows a list of controllers in adjacent regions resp. other ICM positions that can be contacted. The interaction with the different stakeholders could then take place via telephony/voice or text based messages. The Airport display offers a similar functionality including all important airports that can be contacted within neighboring ICM regions. The Airport display contains status information of the selected airport. This includes departures, arrivals, runways in use, aircraft turnaround information and unexpected events.

Via the Flow Management Center display capacity bottlenecks could be identified and solved in advance and communicated to the responsible controller. The Airline Operation Center (OPC) display offers a list of the airlines that are currently in the area of the controllers' responsibility. If necessary the ICM can contact the airlines via headset or by text-messaging. Besides that, flight schedule updates of the controlled flights and actual and planned trajectory information are presented to the ICM. Military OPC display allows for communication about military concerns for flights or airspace restrictions. By selecting an aircraft on the radar screen all corresponding data in the additional displays in the bottom bar are highlighted e.g. airline, airport and ANSP contact and aircraft data.

The three displays on the right of the bottom bar show Aircraft Data, Key Performance Indicators (KPI) and Meteorological Service data. The aircraft data encompasses minimum and maximum speeds, descent and climb characteristics or actual weight and number of passengers. The KPI display may show ratings about costs, capacity, safety and environmental friendliness for single flights and all guided flights. Weather information and forecasts including severity of weather polygons could be shown in detail in the Meteorological Service display, connected to the radar screen if useful.

One key feature of the ICM working position is the team conference monitor. It contains several features of social interaction among the ICM and one or more team members (in this case two tactical controllers and one TMA controller). With option buttons the ICM selects a controller resp. the view of the tactical controllers' traffic situation. Whenever the traffic situation allows it, the ICM introduces a new training unit, i.e. a new approach procedure. As shown in Fig. 2 the ICM invites a selected controller via the team conference monitor to train a certain time based arrival approach by using so called Ghosts and TargetWindows. The ICM working position allows a supervised on-the-job training helping the tactical controller to become more familiar with new procedures while on duty instead of completing after-work training sessions in simulators which are timely demanding and costly. It is obvious, that the job of an ICM requires a well-established knowledge of air traffic management particularly of the future guidance methods as proposed by SESAR.

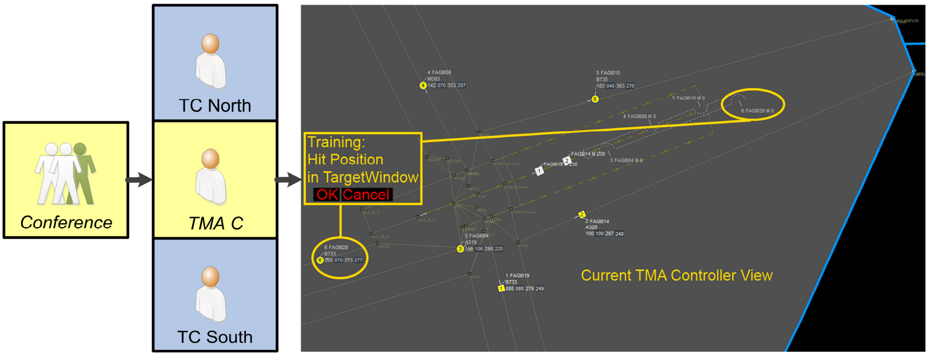

Fig. 2. ICM advises special on-the-job training to TMA controller via HMI

The described amount of information the ICM has to monitor, would definitely exceed the cognitive capacity of a tactical controller in situations under heavy workload. Information regarding the consolidation of conflicts, runway closures or the weather concerning one aircraft or airport can also be "given" to the operational controller by the ICM. The controller again may forward this given advice to a pilot via data link.

Three possible scenarios are explained in the following. If plan deviations occur or a long-term forecasted situation may lead to a conflict, the ICM may advise a conflict solution by changing altitudes and propose it to the most convenient controller. Another scenario refers to the wind direction and intensity. The ICM then advises several noise optimized routes to the operating controller.

If the airline or the pilot wishes to change an arrival route or a procedure, the ICM would check if traffic and weather permits it. After checking the situation, the ICM passes this information to the operational controller. The integration of what-if-solutions for the en-route area to check decisions before delegating to the next controller would be very helpful. All these mentioned points would probably not be handled as easy by a tactical or TMA controller without ICM support.

4.2 Effects of Controller Roles on HMI

The HMI view of tactical controllers will change with the introduction of new guidance steps and our proposed ICM role. One basic possibility is the marking of one aircraft in a general radar screen by any input device to gain more information. In the distance based display the minimum lateral separation around the aircraft can be shown. The vertical distance may be visualized via a three-dimensional view or by warning only if a separation miss occurs. The time based step includes all features of the former step, but shades them darker, because this information will be less frequently used due to pre-regulation. The time based display concentrates on time based separation resp. negotiated target times at different waypoints and marks. Controllers have to check, if all times calculated by a short term flight prediction out of the current flight status can be held. The trajectory based view mainly focuses on the conformance monitoring. Negotiated four-dimensional trajectories with various trajectory points are planned and compared with the real flown way. The information of former displays only appears very dark. The final performance based display shows individual capabilities of the chosen aircraft. It is possible to show the optimum, minimum and maximum time reaching next significant waypoints, rates of climbing, descending, accelerating and reducing, the arrival approach and current weight.

In addition a “channel” for important incoming messages of the ICM should be available. To design the transition as smooth as possible, the former flight strip access could be used. Traditionally paper strips with aircraft information are given to the controller when an aircraft is reaching the area of responsibility. These strips are used to inform and make notes on every single flight and are handed over to the next controller if needed. Some ANSPs already use digital flight strips appearing on the HMI when the aircraft is expected to enter the area of control soon. Important information on weather or critical events could also be noted on special information strips given by the ICM. If the controller accepts the information, he can decide whether to consider or to discard the data. The responsibility to guide air traffic lies within the sovereignty of controllers and therefore is expected to stay largely unchanged even with new roles and HMIs.

5 Summary and Outlook

Many different challenges in ATM will influence controller work in the future. Our proposed new position of an Information-and-Conflict-Manager (ICM) shall get along with information of the system wide information management network concept.

The position is also responsible for training of supervised operational controllers. Additional information and envisaged implementation of the three steps of controller guidance approaches deserve new long-lasting HMI solutions. Nevertheless, hardly any aspect of the challenges is handled in actual controller HMIs. The ICM working position and his tasks will support other controllers to avoid excessive workload. Training of new flight guidance concepts can be done on-the-job and help to successfully overcome the hurdles from one guidance approach step to the other. Besides that, it will reduce costs in simulator-based training.

The theoretical concept was developed due to user-centered design norms. In order to operationally use this concept, a controller evaluation and praxis test is needed. However, the user centered migration tolerant human computer interaction is a way towards future work environmental changes at controller HMIs.

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Developing a Real Time Passenger Information System for Rural Areas

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Abstract. Passengers in rural areas are provided with little or no information regarding public transport disruptions. This can result in high levels of travel uncertainty with significant potential to affect travel behaviour. This paper, through 52 interviews, and 7 focus groups in rural areas in Scotland and England, explores the passenger experience, and the technology usage of individuals during disruption. The analysis indicates that a wide range of behavioural responses are evident, extending well beyond the choice of route or mode of transport. Further, we identify that the individual utilises various technologies (e.g. social media), and kinship networks to insulate against the effects of disruption. In addition, we present the co-design process of a set of technologies (a smartphone application and and an SMS service) that aim to improve the passenger exprience during disruption. This work provides an initial step towards understanding the interplay between disruption, passenger experience, and the design space for improving the passenger experience of individuals during disruption.

1 Introduction

The individual in rural areas usually dont have enough information to make informed decisions during disruption. This has strong impact on those with limited access to private motorised transport such as children, elderly, people with disabilities and the mobility impaired (Velaga et al, 2012a). Even though an increasing number of real time passenger information (RTPI) systems are being developed to provide transport information (e.g. Watkins et al, 2011), the role of real time information in supporting travellers during service disruption is poorly understood, particularly in rural areas.

Our previous work has explored disruption by developing a conceptual model of the passenger recovery phases during disruption, and identified the passenger information requirements for each phase. Further, we have investigated that the passenger behavioural responses to disruption are influenced and shaped by several variables, including, the information that individuals have available during disruption, the quality of information, and the passenger's past disruption experiences (Papangelis et al, 2013a; 2013b). Based on these, in this paper, we: (1) discuss the passenger experience during disruption (2) identify how rural

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 153–162, 2013.

passengers use current technologies (e.g. social media) during disruption to acquire and disseminate information, (3) and present the development process of a smartphone application and an SMS service co-designed with rural passengers.

This work is part of the Informed Rural Passenger[1] (IRP) project, which is adopting a crowdsourcing approach to acquire transport data, such as bus location, directly from the passengers via their mobile phones. This data is integrated using linked data principles with other transport data, such as operator timetables, geographic information system (GIS) roadmaps, and details of disruptions along with other data such as passenger profiles and social networks, within an information ecosystem (Velaga et a. 2012b).

2 Background

Real time passenger information (RTPI) plays a major role in passenger travel decisions during disruptions (Lu, 2011).

Relatively few rural RTPI systems exist; examples include: Warrington Borough variable message sign (UK), the SEStran-supported bus passenger information system in South East Scotland, and the service to enhance rural transit in Amador County in California, USA. This might be because of: (1) fewer passengers; therefore no encouragement to operators to provide current transport information; (2) rural areas being sparsely populated, making it difficult to collect travel/traffic information from the system; (3) the widespread use of request stops by the passengers; (4) and the higher cost associated with developing, deploying and maintaining these technologies in a rural environment (Velaga et al., 2012a).

Further, the lack of RTPI in rural areas results in fragmented and potentially highly inaccurate passenger information. This can lead to very high levels of uncertainty regarding actual travel conditions in the event of disruption. This is especially true in rural areas where the frequency of services is low and passengers tend to make longer journeys. Also, the lack of information to rural passengers regarding service delays or cancellations has severe impact on passenger convenience, comfort and travel behaviour (e.g., exaggerated perceptions of travel time) (Scottish Executive Social Research, 2006).

In this paper, we utilise evidence gathered from interviews and focus groups with public transport users to explore how rural passengers experience disruption, and how they utilise various technologies to disseminate and acquire information during disruption. Further, based on these findings we co-design with rural dwellers a smartphone application and an SMS service that aim to improve the passenger experience during disruption.

3 Methodology

At the beginning of the development process, 52 semi-structured interviews, and four focus groups were conducted. These through the shared culture and

[1] `http://www.dotrural.ac.uk/irp/`

the individual stories of the participants elicited the effects of public transport disruption in the everyday life of rural passengers, and explored their technology usage during disruption. The mean age of the participants was 36.7 years. The interviews were conducted in the Scottish Borders, and the focus groups in the University of Aberdeen, the University of Leeds, and in the island of Tiree.

Based on the data from the initial interviews in the Scottish Borders and the focus groups in the University of Aberdeen, and the University of Leeds four conceptual models were developed. Each conceptual model consisted of a description of a disruption scenario (that emerged during the interviews and the focus groups) and a high level proposed solution for that scenario.

These were presented to the participants in three focus groups in the island of Tiree. The focus groups had 6 participants with a mean age of 32.5 years, and lasted approximately 2 hours. During the focus groups, the participants were asked to discuss the scenarios and the proposed solutions, and grade them depending on how strongly they recognise the problem as being a real problem that they face, and how strongly they agree that the proposed solution would help. Further, the participants discussed the conceptual models and provided feedback on what they liked, disliked and would improve about each solution.

Based on the results of the focus groups, two co-design sessions took place. The sessions were conducted at the island of Tiree, lasted approximately two hours, involved 7 participants with a mean age of 38.7 years. They aimed to explore the design space and design a set of technologies that improve the passenger experience during disruption.

The outcomes of the co-design sessions were refined by 4 interviews with domain experts. These included two academic experts from the Centre for Transport Research[2] of the University of Aberdeen, and two human computer interaction experts interested in the effects of disruption in the everyday life of individuals living in rural areas. All interviews lasted approximately 80 minutes, and aimed to critique and evaluate the proposed designs.

4 Experiencing Rural Travel Disruption

In the areas we studied, disruption was frequent, and expected. This is vividly illustrated in the following quotations "*Whenever I'm going further than my daily commute, I think its always a factor for me", and "I just kind of accept that if I'm going anywhere outside the Aberdeen area there's going to be a delay there's going to be a disruption in my travel plans*".

Further, our data illustrate that some disruptions are more acceptable than others. For example, man-made disruptions (e.g. strikes) are less tolerable than disruptions caused by nature (e.g. heavy rain or high winds). This is illustrated by the following assertion "*I would say that public transportation disruption is man-made and the other we can influence. So that's the main problem, for me. I was very upset when I was stuck somewhere on the beach, it was freezing cold and I couldn't get the bus because they were striking and I didn't know they were*".

[2] `http://www.abdn.ac.uk/ctr/`

The latter quote comes in line with our findings that each individual experiences disruption differently, as one individual's disruption can be another individual's opportunity or inconvenience. This may depend on various factors including personality and previous experience (Papangelis, 2013b). This is illustrated by the following two quotes "*Some things, are just interruptions but Its when it affects what you've planned to do you planned to have your breakfast on the train whilst doing your work because you are getting an early train, when you can't have your breakfast and you can't do your work then that's a disruption but if its someone playing loud music then its not really affecting your plans to sit on that train and get to a destination. For me, that would be the thing: whether it affects what my plans were for the journey*", and " *for example weather things, in my home country its not an issue at all, so this I don't feel as a disruption. It makes it difficult but I don't feel it as a disruption.*" Along the same lines, some individuals living in rural areas don't consider a disruption problematic if they can find ways to work around it. This mainly depends on the type of disruption and on the purpose of travel. For example, individuals have been telling us that if they have to go to the doctor, and there is a bus due to cancellation of the train, they do not consider it a disruption as long as they arrive on time.

Our findings also illustrate that individuals living in rural areas are more prepared to tackle disruptions than their urban counterparts. This is especially true for remote rural places. Individuals are more likely to be prepared for disruption in rural areas with higher chance of systemic disruption. For example, individuals living in the island of Tiree, have been telling us that due to high winds during winter the island can be inaccessible for up to two weeks, and so, they stock food and fuel for up to three weeks during the winter. Further, we have identified that certain groups of individuals are more vulnerable to disruptions than others. These can be summarised as:

- Family with young children
- Individuals without family or friends
- Those living in the outskirts of rural hubs or in hamlets
- Individuals depended on public transportation
- Those who don't have immediate access to a car
- Tourists or Individuals that they don't have knowledge of the locality

In spite of that, they mention that disruption is becoming easier to cope with due to new technologies, as they utilise a great variety of information channels (both formal and informal) enabled by the new technologies (social media, websites, blogs, forums, etc.) to stay up to date, and exchange information (Papangelis et al, 2013a). Figure 1 illustrates an individual living in a hamlet in the Scottish borders informing her twitter followers that the A7 roadworks are causing delays longer than expected.

Moreover, we have identified that kinship networks are also utilised as a way to protect against disruptions (Papangelis, 2013a). Kinship networks are composed of weak ties and strong ties. The strong ties channels are individuals within the passenger kinship networks, which consist of family members, close friends, work

Fig. 1. Correcting and relaying official source information in twitter

colleagues, and school peers that are considered to be as close as familial links (Ebaugh and Curry, 2000). The weak ties are usually friends of people from their strong ties network, or other passengers, where they have a strong dependence on the connectivity to the individuals travel patterns. The information the passengers are seeking from these networks is usually to increase their situational awareness and information on how to mitigate the effects of disruptions. For example, during our passenger interviews, a participant mentioned that during the heavy snowfall in the Scottish borders in 2010, she reached home safely not because of information that the operator provided, but from information that the passenger got from a friend of a friend about a local man going through her village with his snowplough. It was explained in our interview that the same individual, picked up other individuals that he did not know personally along the way only because they had shared common networks and ties. Figure 2 captures these information exchanges during times of disruption among strong ties, weak ties and formal information channels.

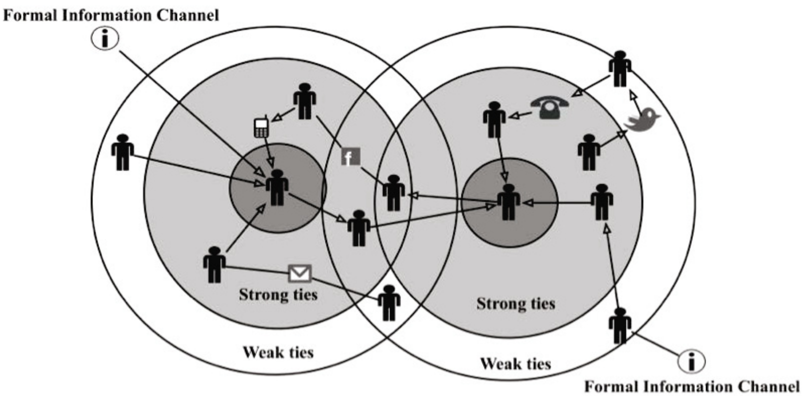

Fig. 2. Information exchange between individuals affected by disruption and their kinship network (Adapted from Papangelis, 2013a)

5 Developing a Rural Real Time Passenger Information System

Real time information has the potential to significantly improve the rural passenger experience during disruption. However, most of the systems are developed for urban areas, and utilise infrastructure not available in rural areas, or use smartphones as the main dissemination channels of information (e.g.Watkins, 2011) . Our work indicates that there is a need for multi-channel dissemination in rural areas as the 3g signal is unreliable, and there is a significant number of individuals with 2nd generation mobile phones. We have identified that the most suitable channels for disseminating RTPI information are: smartphone applications, SMS services, e-mail services, websites, and community displays. The desired functions for each of those technologies as emerged from the interviews and focus groups are as follows:

General functions
Location information
Journey planning
Provision of alternative options in case of disruption
General information about the service
Notification of disruptions
Seat availability
Congestion
Wheelchair/pushcart space
Status of the network
Metrics on quality of information
Route advice to avoid delays
Journey booking capabilities
Ability to create passenger profile, save, store and access information
Functions required on journey
Real time information on own vehicle delays
Information regarding changes, which will affect the passengers journey
Advance warning of changes, which may affect subsequent or later journeys
Information on interchanges
Functions required on boarding point
Waiting time
Information on local amenities
Walking route to connecting modes

As illustrated by the aforementioned functions the technologies should provide both personalised and non-personalised information. According to our studies, the most suitable technologies for disseminating personalised travel information in rural areas are: (a) smartphone applications, (b) SMS services, (c) and e-mail services, while the most suitable technologies for providing non-personalised/public information to rural areas are: (d) community displays, (e) and websites.

During the initial stages of the design of the system, we utilised these functions as emerged from our studies in conjunction with the stories of participants to create four exemplar scenarios illustrating various types of disruption. These were (a) an accident that caused an arterial road to close for a few days, (b) a bus service that constantly runs behind schedule, (c) heavy winds that cut the island of Tiree from the mainland for two weeks, (d) and high congestion of an arterial road. The high level proposed technological solutions were a smartphone application and an SMS service that provided real time bus location information to the users. Both were simple technological solution and were very similar to the ones that already exist in the various smartphone marketplaces.

During the focus groups the participants recognised all scenarios as relatable, and mentioned that both systems are equally useful as long as they provided timely accurate and personalised information. Further, when asked how to improve the technologies, the participant suggested that functions that allow users to validate and update information, and leave comments about a route or a service were required.

Through the focus groups sessions a need for the users to interact with the system, has emerged, "*as during disruption individuals very rarely have right answers and the knowledge to understand and resolve the issues emerged from it*".

Based on that, the concept of 'loose fit' was explored in the four co-design sessions. The participants during these sessions were provided with mock-up tools, and a list with the functions as emerged from the interviews and focus groups and asked to mock-up a prototype of an SMS service and a smartphone application that aim to improve the passenger experience during disruption.

For the SMS system the participants focused in their personal experience to mock-up an SMS service that notifies the user of a disruption, and initiates an SMS based discussion among the users that experience the same disruption. This aims to "*help individuals to understand and resolve the issues emerged from disruption by using the collective knowledge of various individuals that are in the same situation*" by creating ad-hoc *communities of users*" that experience the same disruption. Figure 3 illustrates a scenario where there is a disruption and users organise a car-share through the system.

Further, the participants also designed a smartphone application that aims to improve the passenger experience by: (a) providing information on disruption, (b) allowing the user to validate, and update the disruption information, (c) crowd-source information about the bus service they are in, and (d) allow

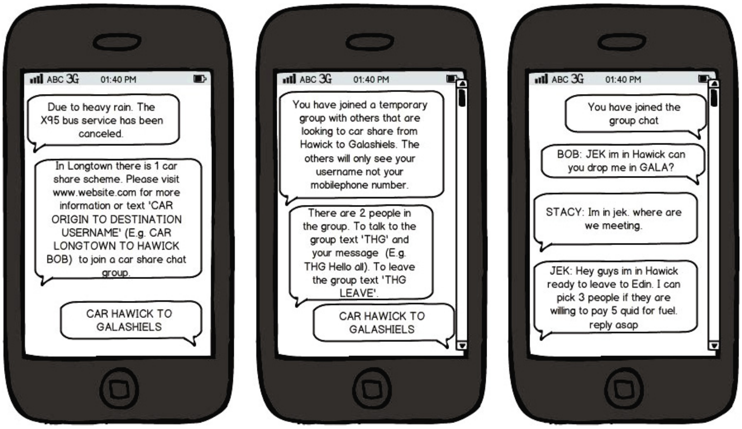

Fig. 3. User notification of disruption and provision of alternatives through group chat

Fig. 4. Mock-ups of the smartphone application that was designed during the co-design sessions

integration of the smartphone application with twitter. Figure 4 illustrates the aforementioned functions.

The various designs as emerged from the four sessions has been further refined through four discussions with domain experts from both the fields of transport studies and human computer interaction. The discussion mainly revolved around the further development of the outcomes, and their integration with the GetThere RTPI that we have developed. The outcomes of these sessions were unified as they all agreed that the outcomes illustrate a need for real time passenger centric information that focuses on the rural passenger needs. Further, they mentioned that the outcomes of the co-design sessions should be further investigated through the exploration of the interactions, and travel behaviour of the passengers (e.g. through wizard of oz studies), before developed into a prototypes or integrated in the GetThere system[3].

6 Discussion and Conclusion

In this paper we have conducted a series of interviews, and seven focus groups in order to explore the passenger experience and technology usage during disruption. Further, based on these findings, we conducted two co-design sessions to design a smartphone application and an SMS service that aim to improve the rural passenger experience during disruption.

Our result indicate that disruption in rural areas is seen as an inherent characteristic of the transport system. Even though it usually leads to frustration, it is often not seen as a problem if there is a way around it. Further, our findings illustrate that rural dwellers are more prepared to tackle disruption than their urban counterparts. However, this depends on the individual, as certain groups are more vulnerable than others. However, in the recent years information and new technologies is making these groups more resilient to disruption. Further, we have identified that during disruption individuals very rarely have right answers and the knowledge to understand and resolve the issues emerged from disruption, and the knowledge is often distributed among various individuals who have different perspectives and background.

Based on these findings we have co-designed with rural passengers a set of technologies - a smartphone application and an SMS service that enable the collaboration of passengers during disruption, with the aim of improving the rural passenger experience during disruption. The designs were further explored through a series of interviews with domain experts, in which they critiqued the design as emerged from the co-design sessions, and gave us suggestions on how to evolve it and incorporate it in our GetThere RTPI system.

Our future research plans include further exploring the design space, the user interactions, the resulting travel behaviour, and incorporating elements of the co-design process in our RTPI system.

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Development of Haptic Assistance for Route Assessment Tool of NASA NextGen Cockpit Situation Display

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Abstract. The NextGen Cockpit Situation Display (CSD), developed by NASA Ames's Flight Deck Display Laboratory, provides advanced flight control functionalities and traffic/weather displays to pilots [1]. Traditionally, the user operates with the CSD using a computer mouse and receives only visual feedback about the controlling actions. In this work, we integrate force feedback in the Route Assessment Tools of the CSD, where the user can manage the flight plan to resolve conflicts in real-time. A spring force, with a variable stiffness coefficient, was used to model the force feedback with its strength varying proportionally to the overall path length. Force display was provided as an indicator of the effort required to deviate from the optimal path to assist the user in decision making. The force feedback models were evaluated on a software testbed created on Microsoft Foundation Class with the Novint Falcon haptic-feedback input device.

Keywords: Multimodal interaction, Haptic feedback, NASA NextGen.

1 Introduction

To improve performance and to meet the current air traffic demands, modern aircraft flight decks have been increasingly automated, and much of the tasks performed by pilots are done by a computer or an embedded system. An example of such technologies is the volumetric Cockpit Situation Display (CSD) developed by NASA Ames's Flight Deck Display Laboratory. This software framework is designed to provide an enhanced visual display and advanced control functions to the pilot for use in real-time flight management. One of the most important tasks for a pilot is to plan routes in order to reach destinations safely and most efficiently, which may require the pilot to modify the aircraft's flight plan in real-time to avoid obstacles (i.e., weather) and traffic conflicts. The Route Assessment Tool (RAT) of the CSD allows the pilot to manage the aircraft's flight plan and utilize available information, such as relative aircraft positions and surrounding weather patterns, to resolve conflicts in real-time.

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 163–172, 2013.

In its current implementation, the user operates in CSD environment using a computer mouse and is only provided with visual feedback of his or her controlling actions. This creates a problem that can adversely affect a pilot's performance and manipulation accuracy because of certain flying conditions, such as turbulence. Our research group has explored a solution to the problem through the addition force displays with a Novint Falcon haptic-feedback input device. Addition of force feedback has been shown to improve the performance of object selection task [2-3]. With respect to movement time, the Falcon with force feedback offers a comparable performance as a mouse; however, it can outperform the mouse for selection of small target sizes and when making diagonal movements.

In this present work[1], we continue the integration of force feedback in the Route Assessment Tool (RAT) of the CSD. Using the RAT, the user can manage the flight plan and utilize available information, such as nearby aircraft positions and surrounding weather patterns, to resolve conflicts in real-time. We developed a force display to assist the pilot with the route manipulation task, as he/she modifies the route from the original path. With the implemented model, the strength of the force feedback varies proportionally to the change in the overall path length indicating the effort required to deviate from the optimal (or original) path. The force feedback provides augmented information, so the operator would still make the final decisions. The subsequent sections describe the prior work, the implementation of the force-feedback model, and a user study with a testbed system.

2 Prior Work

Haptic feedback has been previously known to be effectively utilized in various applications [4-13]. Semere et al. [4] performed user studies on teleoperated surgical procedures, and found that the presence of force feedback helped improve the surgeon's accuracy and efficiency, though the overall time of surgery was not significantly improved. In minimally-invasive surgery, Wagner et al. [5] observed that tactile feedback provided when the tool is making contact with tissues improves accuracy by reducing the amount of surgical mistakes such as accidental punctures. In teleoperated uninhabited aerial vehicles, Lam et al. [6] showed that force feedback reduces the number of vehicle collisions. Furthermore, Farkhatdinov et al. [7] conducted a user experiment study and found that variable gain for force feedback output in a teleoperated robot helped improve accuracy and the quality of manipulation by allowing smoother movements.

Related to the NextGen CSD, Robles et al. integrated force feedback in object selection tasks [2], which Rorie et al. used to evaluate the effect of force feedback as compared to the performance of a computer mouse in a Fitts' law task [3]. A commercial haptic device, called the Novint Falcon, was used as the force-feedback input device. The results showed that the Falcon with force feedback produced faster

[1] This work is supported by NASA cooperative agreement NNX09AU66A, Group 5 University Research Center: Center for Human Factors in Advanced Aeronautics Technologies (Brenda Collins, Technical Monitor).

movement times than a mouse when moving the cursor in a non-vertical or non-horizontal line. There was no difference in performance with the two devices, though, when the movement was along a vertical or horizontal line. Thus, the Falcon with force feedback produced better movement time than a mouse for smaller targets. This finding is consistent with those obtained by other researchers [14]. Thus, the existing research suggests that there is a potential benefit for the use of force feedback to improve the efficiency of operator interactions with the CSD.

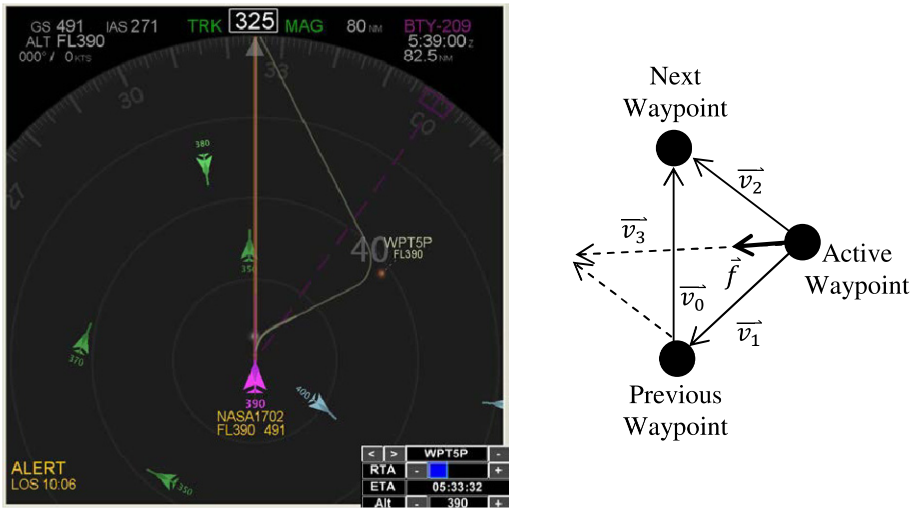

Fig. 1. (Left) A view of the CSD as the user moves a waypoint, shown by the orange dot labeled as WPT5P, through the Route Assessment Tools to create a new route shown by the gray curve. (Right) A vector diagram used for the force feedback calculation. A color version of the figure is available in the electronic copy of this paper.

3 Force Feedback Integration with the CSD

3.1 Force-Feedback Model for Route Manipulation

To extend the application of force display within the CSD functionalities, a new force feedback model was created for the route manipulation task that can be accomplished through use of the Route Assessment Tool (RAT). To modify an existing route using the RAT, the pilot creates a new (active) waypoint by clicking on a line representing an existing route. The path changes as the active waypoint is moved to a new position as shown in Fig. 1. As the user moves the active waypoint away from the original path, the overall distance increases and potential conflicts with nearby aircrafts and/or obstacles may arise. To warn the pilot of such changes, we developed a force model that simulates stretching of a rubber band to represent the action that occurs during route manipulation. The force model applies a linear spring force with a variable stiffness coefficient, which changes proportionally to the increase in the overall path length. The rise in the magnitude of the force display implies the effort required to deviate from the optimal (or original) path, which can be used as an indicator of undesirable outcomes, such as longer flight time and higher fuel usage.

Fig. 1 (right) illustrates the calculation of the output force, $\vec{f}$, in a simple scenario with one via point, shown as the *active* waypoint. $\overrightarrow{v_0}$ represents the original path, where $\overrightarrow{v_1}$ and $\overrightarrow{v_2}$ are the new path segments that are generated from moving the active waypoint. The magnitude of the force depends on the difference between the lengths of the new route and the original route, while the direction of the force is dictated by the sum of the vectors $\overrightarrow{v_1}$ and $\overrightarrow{v_2}$, as shown in Fig. 1 (right). The directional vector $\overrightarrow{v_3}$ was defined as.

$$\overrightarrow{v_3} = \overrightarrow{v_1} + \overrightarrow{v_2} \tag{1}$$

The increase in the overall path length can be calculated from

$$d = \|\overrightarrow{v_1}\| + \|\overrightarrow{v_2}\| - \|\overrightarrow{v_0}\| \tag{2}$$

Then, the output force can be computed from.

$$\vec{f} = kd\widehat{v_3} \tag{3}$$

where $\widehat{v_3}$ is the unit vector of $\overrightarrow{v_3}$ and a scalar k is introduced as an overall gain. As more path segments are created, the calculation of d is modified to include the entire path history.

3.2 Implementation on a Testbed System

While the force-feedback model is currently being integrated into the CSD framework, we were first interested in evaluating the effect of the new force feedback model on the performance of a route manipulation task. To accomplish this, a testbed software was developed in the Microsoft Foundation Class. A static image of the 2D flight plan display of the CSD is used as the background. The task simulated a simplified route modification task with one waypoint and one obstacle. An obstacle is created as a circle in which its location and diameter can be changed depending on the experimental condition. The obstacle simulates a real obstacle that can occur during flight, such as a weather pattern or a nearby aircraft that must be avoided when creating a flight plan change. The new waypoint and the new route can be created by the same click and drag motion as with the CSD. A waypoint is created on the existing route by clicking on any location along the route. The user can then drag the waypoint to another location to create a new route. Fig. 2 (left) shows the new route, with the black circle denoting the active waypoint, and the white line showing the new route. The Novint Falcon is used as the force-feedback input device, as shown in Fig. 2 (right). The Novint Falcon is a 3D joystick that moves in 3 dimensions of force, with feedback up to 2 lbs. It has a position resolution of 400 steps per inch and a workspace volume of 4in x 4in x 4in, yielding the total resolution of 1600 x 1600 x 1600 steps. Since the task was two-dimensional in nature, a virtual unidirectional plane was programmed to limit the range of movement for the Falcon to a planar surface creating movement similar to using a computer mouse on a physical surface.

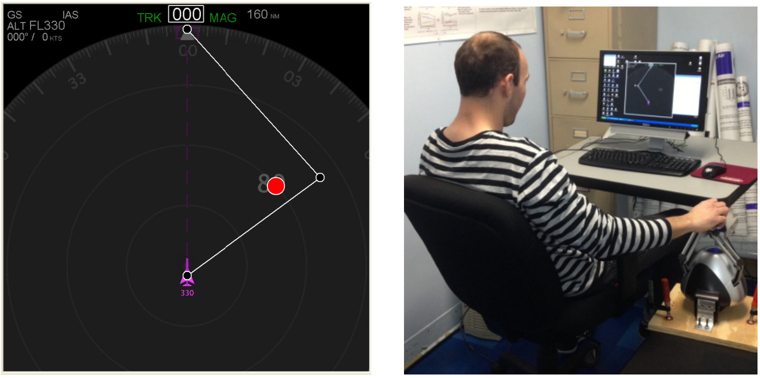

Fig. 2. (Left) the MFC testbed with the new route shown white line as created to avoid the obstacle shown as a red circle. (Right) User experiment apparatus with the Novint Falcon oriented to point upward, and its height is set at the level of the participant's armrest. A color version of the figure is available in the electronic copy of this paper.

4 Evaluation of the Effect of Force Feedback

4.1 User Experiment Overview

The experiment was conducted with the Falcon input device and baseline conditions using a Logitech laser mouse were included. Since the task was two-dimensional in nature, a virtual unidirectional plane was programmed to limit the range of movement for the Falcon to a planar surface. While the Falcon is typically oriented to accommodate hand motion in the plane parallel to the orientation of the visual display, in the present study, the device was turned 90 degrees to allow hand movement in the horizontal plane (i.e., perpendicular to the visual display.) This was done to maintain a similar form of manipulation relative to the mouse condition as well as to improve participant comfort while using the device. Buttons located on the Falcon's interchangeable grip allowed participants to select targets as they would with the mouse. The height of the grip was set at the level of the participant's armrest. Fig. 2 (left) illustrates the physical environment of the experiment. The start and obstacle icons were displayed using a screen shot of a CSD, where no traffic was present. The CSD display was 8" x 8", presented on a 17" x 11" computer monitor with 1680-pixel x 1050-pixel resolution. Participants sat roughly 20 in. from the computer monitor. The worktable was aligned with the height of the chair's armrests, so that movements in all conditions could be accomplished with the arm resting on the chair. An experimenter remained in the room with the participants for the duration of the experiment in order to field any questions and activate the program between trials.

4.2 Experimental Design and Data Collection

Participants performed a simple waypoint selection task with both input devices: the Novint Falcon with three levels of force feedback and the Logitech computer mouse.

At the beginning of each trial, the predetermined route and an obstacle were displayed. Participants started a trial by clicking any point along the vertical predetermined route to select a waypoint; then, they clicked and dragged the waypoint around the obstacle as quickly as possible and released the waypoint to end the trial. Movement times were recorded for each trial. After the waypoint was released, the start point and obstacle stimuli for the next trial were presented. The task was therefore self-paced, as the trial did not begin until the start location was clicked.

Table 1. Levels of each independent variable

Variable	Levels
Target Size	10 pixels, 20 pixels (Radius)
Target Horizontal Distance	125 pixels, 250 pixels
Force Level	0, 10, 30, 50 mN/pixel

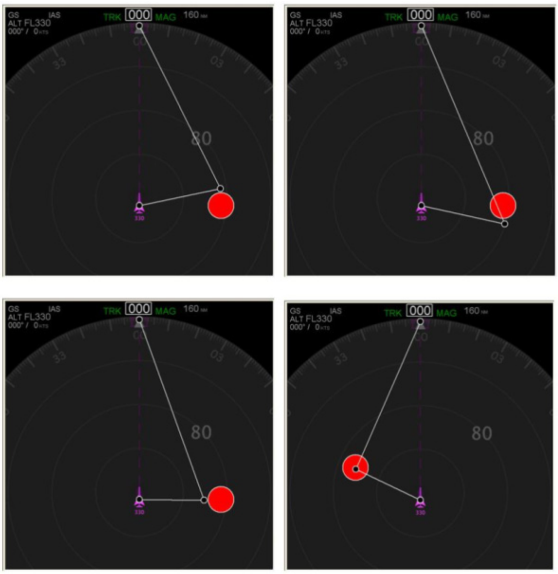

Fig. 3. Examples of inaccurate obstacle avoidance outcome

The predetermined route was always located at the center of the display at the beginning of each experimental trial. Obstacles varied in size and distance from the predetermined route for each trial. Two obstacle sizes of radii 10 pixels and 20 pixels, and two horizontal obstacle distances away from the predetermined route of 125 pixels and 250 pixels were used. Three vertical obstacle locations were used, however, since participants the starting location (i.e. they were allowed to place their starting waypoint anywhere along the starting route), vertical distance was not coded in the results. Each size, horizontal distance, and force combination was presented to the participant randomly, for a total 72 trials per test block.

The experiment employed a 2 (Target Size) x 2 (Target Distance) x 4 (Force Level) repeated measures design, as shown in Table 1. The order of presentation for the obstacle variables (i.e. size, and distance) and the force level were randomly generated for each participant. The dependent variables were movement time, recorded to the nearest millisecond, and overall accuracy. Accuracy was determined by two factors: obstacle overlap and horizontal waypoint placement (refer to Fig. 3). Obstacle overlap was considered inaccurate if the distance between the centers of the waypoint and obstacle was less than the sum of their radius. Horizontal waypoint placement was considered inaccurate if the inside edge of the waypoint (i.e. the side of the waypoint

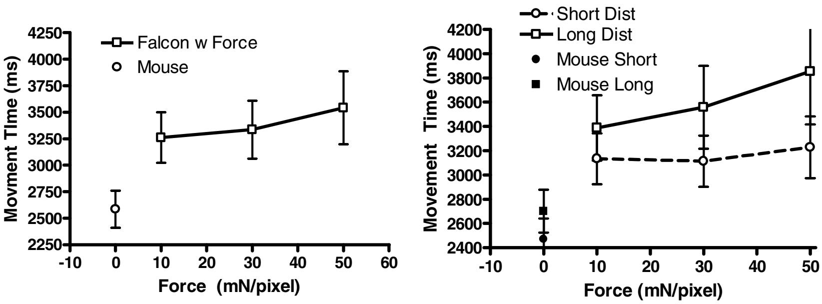

Fig. 4. Movement time comparison between computer mouse and Falcon with force feedback

nearest to the center) was placed on the inside of the vertical center line of the obstacle. Overall accuracy was the combination of these two accuracy metrics.

Six students from California State University, Long Beach participated in the experiment. They were paid 30 dollars at the conclusion of the study for two, one-hour sessions and an addition half hour session over three days. All six of the subjects were male, reported being right handed, had a lot of experience with a standard computer mouse and limited previous experience using the Falcon. Each participant completed a practice block on the first day of testing with the Falcon. The practice block consisted of two trials of each combination of the variables. Each test block took an average of seven minutes to complete. Upon completion of a block, participants were provided with a brief rest period before starting the next block. Participants completed three to ten test blocks per day, depending on device condition, in a single session lasting about 60 minutes. All blocks for one device were completed before moving to a new device, with the order of device blocks partially counterbalanced.

5 Results and Discussion

5.1 Movement Time

We found a marginally significant main effect of force, $F(2,10) = 5.728$, $p = .06$, such that movement time tended to increase with the amount of force feedback (10mN/pixel $M = 3261$ ms; $SEM = 238.3$ ms; 30 mN/pixel; $M = 3335$ ms; $SEM = 273.1$ ms; 50 mN/pixel; $M = 3541.3$ ms; $SEM = 344.4$ ms). Movement time for the mouse was lower overall as seen in Fig. 4 (left). We also found significant main effects of distance, $F(1,5) = 10.69$, $p = .02$, and size, $F(1,5) = 6.71$, $p = .05$. Movement time increased with distance (short: $M = 3158$ ms; $SEM = 224.3$ ms; Long: $M = 3600$ ms; $SEM = 347$ ms). With respect to the target size, the participants took longer to position behind smaller targets than larger targets (10-pixel targets: $M = 3430$; $SEM = 287.3$ ms; 20-pixel targets: $M = 3328$ ms; $SEM = 282.8$ ms).

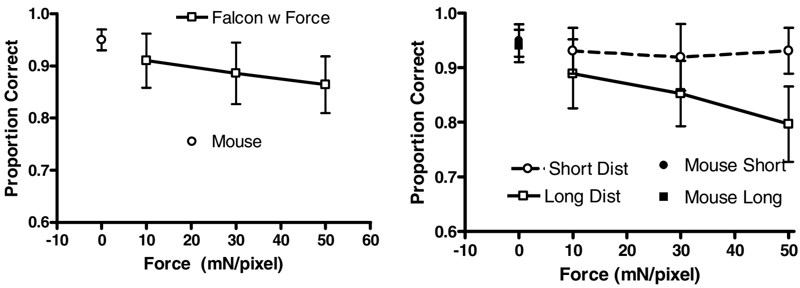

Fig. 5. Accuracy comparison between computer mouse and Falcon with force feedback

We also found a significant interaction of force and distance, $F(1,5) = 6.71$, $p = .01$) as shown in Fig. 4 (right). For the short distance, the level of force feedback had little impact on movement time, but for the long distance movement time increased almost linearly with the amount of force. For all force feedback levels, movement times were longer than that obtained with a mouse. The increase in movement time with the presence of force feedback was expected for an object avoidance task where the amount of force feedback increases proportionally to the deviation from the preferred path. That is, as the distance to the target increases (or with higher gain), the user is required to exert more effort to resist the force feedback to make the route modification. This finding suggests the use of low force feedback could reduce the negative effect on movement time.

5.2 Accuracy

A significant main effect of force, $F(2,10) = 6.54$, $p = .01$, and distance, $F(1,5) = 13.6$; $p = .01$) was found. Accuracy decreased overall with force feedback

(10 mN/pixel: *M* = .91 *SEM* = .05; 30 mN/pixel: *M* = .89, *SEM* = .06; 50 mN/pixel *M* = .86; *SEM* = .05) as seen Fig. 5 (left). Accuracy also decreased overall with distance (*Short*: M = .93, *SEM* = .05; Long: *M* = .85, *SEM* = .06). We also found a significant interaction between force and distance, $F(2,10) = 4.175$, $p = .05$, which can be seen in Fig. 5 (right). With force feedback, the accuracy was the highest at the short distance. At the long distance, accuracy decreased with force feedback. Accuracy at the short distance was about equal to the accuracy of using a mouse similar to the movement time results, too much force feedback decreased accuracy, as the user needed to overcome the force feedback to make the route modification. Since the force model for route manipulation increased proportionally to the overall path length, the amount of force feedback will be generally low when the obstacle is closer. Again, these findings suggest that an appropriate level of force feedback can be applied to yield similar accuracy performance to a mouse.

6 Conclusions

In the present paper, we report a new force-feedback model that was developed for the route manipulation task of NASA Flight Deck Display Research Laboratory's volumetric cockpit situation display. The effect of force feedback on the performance (movement time and accuracy) was evaluated in a user study using a testbed system and the Novint Falcon haptic device as the input device. During the experiment, the users were asked to modify the aircraft's current flight path to avoid an obstacle. Based on the experimental results, the amount of force feedback provided had a significant effect on both movement time and accuracy. Force feedback increased the overall movement time and decreased accuracy as compared to the performance with a mouse. With the route manipulation task, the force feedback model implemented was designed to be used as an indicator of the change to the overall path. As the force increases to resist the user's motion away from the optimal path, the adverse effect of force feedback on performance is anticipated, as found in prior research [15]. Thus, the effect on movement time may not be the most suitable dependent measure to use in evaluating of the true benefit of the force feedback model. The experimental results, however, support the notion that appropriate selection of force feedback level can provide comparable accuracy to a mouse, and may lead to a better performance. To further evaluate the effect of force feedback for route manipulation, obstacles with more complex geometry that will require modification of multiple route segments should be employed. Qualitative factors including the efficiency of the modified path with respect to flight time and fuel cost should also be considered in future studies.

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Cloud Computing and the Internet of Things: Technology Innovation in Automobile Service

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Abstract. Aiming to explore the transforming role of information technologies in automobile service, this paper first introduces two major technology trends: Cloud Computing and the Internet of Things, as well as their applications in automobile service. After that, the paper focuses on investigating the technology innovations in automobile service, and how the innovations transform the traditional business. Future research directions are discussed finally.

Keywords: Cloud Computing, the Internet of Things, Service Applications, Technology Innovation, Automobile Service.

1 Introduction

The automotive dealership business is undergoing significant change triggered by advanced information technologies, especially Cloud Computing and the Internet of Things. Aiming to explore the transforming role of information technologies in automobile service, this paper first introduces two major technology trends: Cloud Computing and the Internet of Things, as well as their applications in automobile service. After that, the paper focuses on investigating the technology innovations in automobile service, and how the innovations transform the traditional business. Future research directions are discussed finally.

2 Technology Background

2.1 Cloud Computing

Cloud computing is changing the Information Technology (IT) industry fundamentally by transforming computing services to an on-demand model similar to electronic and water utilities [1, 2]. Utilizing cloud computing, IT providers deliver the subscription-based services at three different levels including infrastructure, platform, and software applications (as shown in Table 1). IT users access computing services over the Internet in a pay-as-you-go model without investing heavily on technology development and maintenance in house [2].

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 173–180, 2013.

Cloud computing benefits both the IT providers and the users. For the IT providers, cloud computing creates a data center on a virtual base, meaning the IT infrastructure such as hardware and software can be physically distributed but logically connected. This component-based architecture enables the IT providers allocate the IT resources efficiently and save costs at the same time. For the IT users, they are able to access the IT services anywhere anytime with competitive costs. Additionally, cloud services free the IT users from building complex IT infrastructure on site, thus allow them focus more on product innovation and increase core business value.

Cloud computing has great business potentials. IDC (International Data Corporation) anticipates the worldwide cloud spending will grow from $40 billion in 2012 to $100 billion annually by 2016 [3]. Moreover, Gartner Group identifies cloud computing as one of the top IT trends that will reach its peak in two to five years [4]. Cloud computing has been widely explored and deployed in various areas such as e-business (e.g., Amazon Elastic Compute Cloud), social networking (e.g., Facebook and Myspace), searching engine and portal (e.g., Google App Engine), online storage and collaboration (e,g., Dropbox and Microsoft Skydrive), infrastructure services (e.g., Sun Network/Sun Grid and IBM Blue Cloud Computing), and enterprise applications (e.g., Salesforce), etc.[5].

Cloud computing can be classified in terms of the service types and the service range. Table 1 illustrates the different models based on the two classifications.

Table 1. Classification of cloud computing models [6]

Cloud computing models		
Service models (Service type/level)	Infrastructure as a Service (IaaS)	Infrastructure such as network, servers, operating systems, and storage etc.
	Platform as a Service (PaaS)	Platform such as programming languages and tools, database, and web server etc.
	Software as a Service (SaaS)	Software applications such as client interface, and enterprise applications etc.
Deployment models (Service range/scale)	Public cloud	Available to general public
	Community cloud	Shared by several organizations
	Private cloud	Operated solely inside of an organization
	Hybrid cloud	Composed two or more clouds (private, community, and/or public cloud)

2.2 The Internet of Things

The Internet of Things (IoT) is another major trend that shapes the development of Information and Communication Technologies (ICT) by connecting “everything” to the Internet [7]. As an emerging paradigm, IoT converges three primary visions (as shown in Fig. 1) including things (the objects to track, things-oriented vision), networking (the connection of the objects to the Internet and communication between the objects, Internet-oriented vision), and representation (the representation of the objects on the Internet, semantic-oriented vision).

The “things” in IoT could be any objects that need to be tracked in practice, for instance, cars on road, products in inventory, and even pets on the run. The “things” feature three main characters; they have to be 1) identifiable, 2) able to communicate, and 3) intelligent [7, 8].

In order to capture the above attributes of the “things”, several technologies has been utilized [9]:

- **Identification technologies.** The essential component of IoT includes identifier such as Radio-Frequency Identification (RFID) tags and two-dimensional bar code. Those identifiers can be used to uniquely identify objects, as well as their status such as location, temperature, and movements, etc.
- **Sensing and communication technologies.** Sensors combined with communication technologies can be used to track the changing status of an object, and transmit the data to the Internet, for example, Wireless Sensor Networks (WSN) and RFID Sensor Networks (RSN).
- **Middleware technologies.** The middleware hides the details of different technologies, integrates the legacy technologies at lower level, and provides a unified interface to support the development of specific applications at higher level.

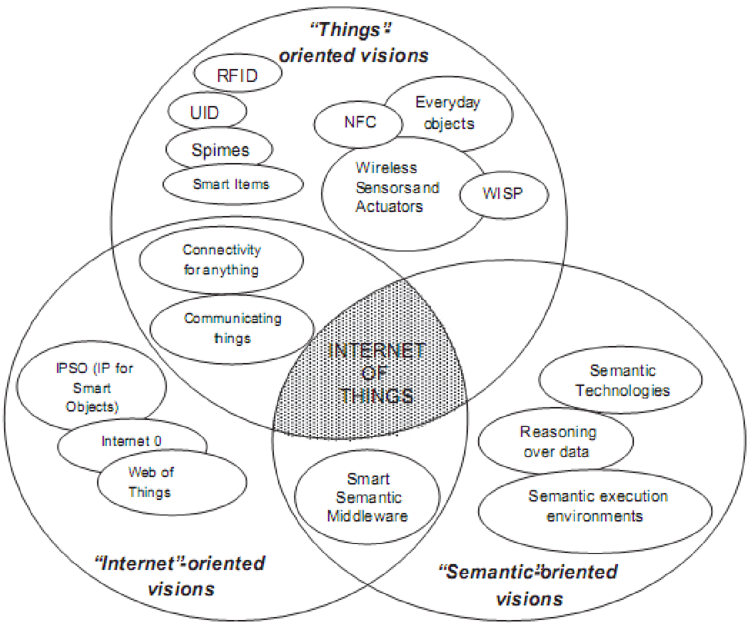

Fig. 1. “The Internet of Things” paradigm as a result of the convergence of different vision [9]

IoT creates a dynamic network of identified mobile "objects", which communicate and interact with one another in order to support business applications and management [8]. By tracking objects and connecting data to the Internet, IoT brought tangible business benefits such as increasing logistic efficiency, improving life-cycle management, and creating value-added services.

2.3 Current Applications and Challenges

Business Applications of Cloud Computing and the Internet of Things. In many situations, IoT and cloud computing have been used together to create the dynamic network of mobile objects. The former mainly focuses on tracking the physical objects and connecting the data to the Internet, while the latter emphasizes the storage and the management of the mass information over the Internet. Both work together to provide ubiquitous, convenient, and on-demand service to the users.

IoT and cloud computing have started to play an important role in various areas such as environmental monitoring, smart cities, inventory control, healthcare, and security vs. surveillance [7]. In automobile industry, for instance, manufacturers such as Honda introduce RFID to manage the supply chain. CarMax, the largest used car retailer in the U.S., attaches RFID tags to each vehicle, in order to track the life cycle of a vehicle from buy-in, refurbishment, to retail/auction [13].

BMW has adopted iDrive (intelligent-Drive) as an intelligent informatics system. Using various sensors and tags, iDrive keeps track of the driving data and the environment information in order to assist drivers make instant decisions and allow them to concentrate on road [12]. With an embedded GPS (Global Position System), iDrive is able to track the vehicle location and the road condition to provide driving directions. If a BMW is stolen, the driver could locate the stolen car through the BMW tracking system. Moreover, iDrive provides remote services such as medical rescue and remote diagnose.

In addition to BMW, other major manufacturers such as Toyota, GM, and Ford also deployed informatics system (i.e., Toyota G-Book, GM OnStar, and Ford SYNC) in their newly released models.

Challenges and Opportunities. Since cloud computing and IoT are still in their infancy, they face a few challenges. Security is the first critical issue to adopt IoT and cloud computing wide spread [7,10]. The main concerns include availability and stability of the service, data confidentiality and security, information privacy, scalability of the storage, and reputation of the providers, etc. [7]. The major cloud providers such as Amazon, Google, and Microsoft, all implemented security mechanisms aiming to provide reliable computing and secure communication [10].

The other main challenge is global standards. Global standard in the areas of security, privacy, architecture, and communications are essential to avoid conflict between and confusion of locally developed standards in enterprise or industry wise.

Though with challenges, IoT and cloud computing provide opportunities for technology innovation in industries, even for those brick-and-mortar companies. For instance, enabled by IoT and cloud computing, "things" such as vehicles can be connected to add security, analytics, and management capabilities [11]. Following we introduce two cases of the applications of IoT and cloud computing in automobile industry.

3 Technology Innovation in Automobile Service

3.1 Transforming Automobile Service

New information technologies such as IoT and cloud computing are transforming the traditional dealership process and operations. The life cycle of automobile service normally includes marketing and sales, service and survey, and finally recycling and used-car sales. Enabled by IoT and cloud computing, dealership is able to track car usage and analyze consumer preference along the life cycle, thus increase efficiency and improve customer satisfaction.

For instance, the future showroom could become an experience, education, and entertainment center, or even a social club rather than the traditional sales center. Since the majority of the pre-sale activities (such as model comparison, price enquire, and appointment scheduling) and sales operations (such as checking credit, signing contract, and shopping loan) can be completed online or through mobile devices, the main purposes of visiting a showroom change to gain experience (of new models or new technology embedded in car), education (on vehicle-related lessons), entertainment (on virtual games and kids club), or social interactions (with people of similar interests on driving, design, and car maintenance, etc.) The above vision breaks the "normal" pattern. It has to be supported by information technologies such as IoT and cloud computing by tracking and analyzing the mass data of driving behavior and consumer preference.

Table 2 shows the transformation of the automobile services enabled by information technologies such as IoT and cloud computing.

IoT and cloud computing initiate the technology innovation in automobile services. According to Francisand and Bessand [14], there are four different 'targets' of innovation:

- **Product innovation:** the development of new products or the improvement of existing products.
- **Process innovation:** the improvement of processes that create the product.
- **Position innovation:** a product is repositioned in a different user context.
- **Paradigm innovation:** meaning the dramatically changing business model requires a shift in organizational values and power structures.
- For each type, innovation can reach two different levels [14]:
- '**Do better**' innovation continues innovative activities along the same path.
- '**Do different**' innovations are innovations that completely change the current portfolio activities.

The technology-enabled innovation in automobile service mainly includes three different types of innovations: product (i.e., service) innovation, process innovation, and paradigm innovation. The innovation may reach different levels at different time frame (see Fig. 2).

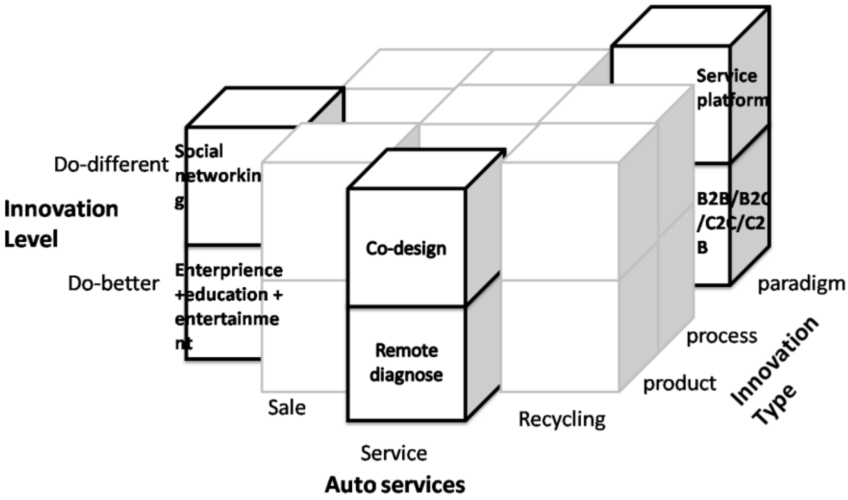

Fig. 2. Dealership service innovation

Table 2. Transformation of automobile service

Auto service	Traditional model	Transformed model
Sales	Test-drive, negotiate, check credit, shop auto loan, and sign contract.	• Experience center: experience new models and state-of-art technologies • Education center: gain knowledge related to model selection, car maintenance, and driving safety, etc. • Social networking: get together with people who share the similar interests related to automobile design, driving, and maintenance, etc. • Entertainment center: virtual driving games, kids club, etc. • Mobile commerce: offer pre-sale activities and sales operations via mobile devices
Service	Wait for customer to take the car to the garage, fix it, and notify the customer	• Track vehicle usage and road condition, assist driver to make instant decisions. • Provide remote services such as tele-diagnose • Initiate personalized service by offering entertainment, news, commercial information based on driver preference

3.2 Technology Architecture

Specific technologies have to be deployed to support the applications of IoT and cloud computing in automobile service industry. Identification technologies (such as RFID tags and sensors) can be used to track the status change along the life cycle of a vehicle, a customer, and auto service. Communication technologies (such as WSN and satellite network) can be used to connect the mass data to the Internet (i.e., cloud). Applications can be developed to analyze the tracking date in order to understand the customer behavior and the vehicle usage. These technologies together enable the innovation of automobile services (as shown in Fig. 3).

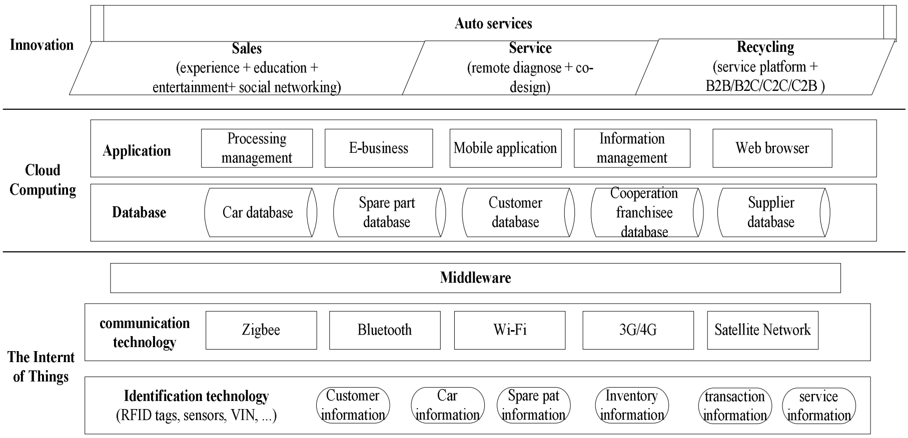

Fig. 3. Technology architecture in dealership innovation

4 Conclusion

The automotive dealership business is undergoing significant change triggered by advanced information technologies. This paper first introduced the two major technology trends: the Internet of Things and cloud computing. Using automobile service as an example, this paper then focused on the technology innovations that are transforming the traditional “passive” pattern to future “proactive” mode.

Future research may explore the methodologies of the innovation design, the procedures of the transformation in practice, as well as the issues raised during the implementation.

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Visualization of Anomaly Data Using Peculiarity Detection on Learning Vector Quantization

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Abstract. The purpose of this research is to develop the control chart robust for complex multidimensional data. In this study, we propose the methodology of anomaly data visualization and detection using hybrid model of Learning Vector Quantization (LVQ) and Peculiarity Factor (PF). LVQ is neural network model which uses supervised learning algorithm. It is useful to classification of multidimensional data with nonlinearity and multi-collinearity. PF is a criterion for evaluating peculiarity and is widely used for outlier detection. In the proposing method, PF of input data is calculated using the weight vector of LVQ. The anomaly data assigned to the class of the normal data was able to be displayed as an outlier on the control chart by calculation of PF on LVQ. The proposed model realized the robust discernment and visualization of the anomaly data that have complex distribution by small computational complexity.

Keywords: Learning Vector Quantization (LVQ), Data Visualization, Peculiarity Factor (PF), Nonlinear Multidimensional Data, Control Limit.

1 Introduction

The purpose of this research is to develop the control chart robust for complex multidimensional data. It is very important to distinguish anomaly data and normal data in quality control and data analysis. In this task, statistical models of anomaly data function effectively when user has enough anomaly data or information of anomaly. On the other hand, statistical models of normal data function effectively when user doesn't have enough anomaly data. In general, it is rare that information of anomaly states or these data are sufficiently given. For this reason, outlier detection on statistical models of normal data is used widely. However, since the accuracy of unusual detection of the statistics model about a normal value is dependent on the data representation capability of a model, these models have to improve the discernment accuracy of data. Furthermore, these models don't function effectively, when anomaly data are sampled abundantly and are formed clusters in a certain region (see Fig.1).

In this study, we propose the methodology of anomaly data visualization and detection using hybrid model of Learning Vector Quantization (LVQ)[1] and

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 181–188, 2013.

Peculiarity Factor (PF)[2]-[4]. LVQ is useful tool for discrimination of multidimensional data with nonlinearity and multi-collinearity and is used for various scenes, such as data mining. So, it is helpful in understanding of multidimensional quality data and detection of anomaly data. Anomaly detection by LVQ functions effectively in data regions where data of anomaly value was obtained sufficiently, but these methods may discriminate data of anomaly data as normal data frequently, when anomaly data isn't obtained sufficiently. Then, detection of the abnormal value data which is not discriminable only by LVQ is also enabled by calculating PF to the set of weight vectors by which the class division was labeled as the normal value of LVQ.

2 Hybrid Model of LVQ and PF

2.1 Learning Vector Quantization (LVQ)

Learning Vector Quantization (LVQ) is a 2-layered feed-forward neural network model that is closely related to the self-organizing map (SOM) algorithm. LVQ which uses supervised learning algorithm is useful to classification of multidimensional data with nonlinearity and multi-collinearity.Recently, such machine learning models are used in the quality control field[5][6]. A set of nodes of LVQ is constituted by weight vectors $\{\boldsymbol{w}_1,\boldsymbol{w}_2, \dots ,\boldsymbol{w}_{N-1},\boldsymbol{w}_N\}$and class information $\{c_1,c_2, \dots ,c_{N-1},c_N\}$.Where, N is the number of nodes of LVQ.

2.2 Peculiarity Factor (PF)

Peculiarity Factor (PF) is a criterion for evaluating peculiarity and is widely used for outlier detection. PF is calculated based on the distance between each data of variables. It can visualize the size of gap from other data of each data in relative positional relation with other data by using this.These criteria are defined as follows. Let, X=$\{x_1, x_2, \dots , x_{n-1}, x_n\}$ be n sampled dataset with $\boldsymbol{x}_i$ =$(x_{i1},x_{i2}, \dots ,x_{im})$. For the dataset X, the attribute PF of x_{ik} is defined by

$$PF(\boldsymbol{x}_{ij}) = \sum_{k=1}^{n} N(\boldsymbol{x}_{ij}, \boldsymbol{x}_{kj})^{\alpha}, \tag{1}$$

where α is a parameter and $N(\boldsymbol{x}_{ij}, \boldsymbol{x}_{kj})$=$\|\boldsymbol{x}_{ij} - \boldsymbol{x}_{kj}\|$. And, for the dataset, the record PF of the point x_i is defined by

$$PF(\boldsymbol{x}_i) = \sqrt{\sum_{j=1}^{n} \beta \times (PF(\boldsymbol{x}_{ij}) - PF(\boldsymbol{x}_{ij}))^2}, \tag{2}$$

where β is a weight parameter of attribute, and $PF(\boldsymbol{x}_{ij})$ is given by Equation(1).

2.3 Proposed

Hybrid model of LVQ and PF for discernment of anomaly data which cannot perform assignment of a class in LVQ has been proposed. In the proposing method, PF of input data is calculated using the weight vector of LVQ. Let, $Y = \{\boldsymbol{y}_1, \boldsymbol{y}_2, \ldots, \boldsymbol{y}_{N-1}, \boldsymbol{y}_N\}$ be r sampled dataset that is classified into the normal class with $y_i = (y_{i1}, y_{i2}, \ldots, y_{ir})$. For the dataset Y, the attribute PF of y_{ik} is defined by

$$PF_{lvq}(\boldsymbol{y}_{ij}) = \sum_{l=1}^{q} N(\boldsymbol{y}_{ij}, \boldsymbol{w}_{ij}^{NML}) = \sum_{l=1}^{q} \|\boldsymbol{y}_{ij} \boldsymbol{w}_{ij}^{NML}\|, \tag{3}$$

$$PF(\boldsymbol{y}_i) = \sum_{l=1}^{q} \sqrt{\sum_{j=1}^{m} \beta \times (PF(\boldsymbol{x}_{ij}) - PF(\boldsymbol{x}_{ij}))^2}, \tag{4}$$

where, $\boldsymbol{w}_{NML}$ is weight vector of LVQ nodes that is labeled as normal data. The control chart of multidimensional data with nonlinearity and multi-collinearity can be created by carrying out the time series plot of the value of this PF_{lvq}.

$$PF(\boldsymbol{x}_i) = \sqrt{\sum_{j=1}^{n} \beta \times (PF(\boldsymbol{x}_{ij}) - PF(\boldsymbol{x}_{ij}))^2}, \tag{5}$$

The upper control limit (UCL) of the control chart based on PF_{lvq} is defined by

$$UCL_{lvq} = \frac{1}{n} \sum_{i=1}^{n} PF_{lvq}(\boldsymbol{y}_i) + \gamma \sqrt{\frac{1}{n} \sum_{i=1}^{n} \left(PF_{lvq}(\boldsymbol{y}_i) - \overline{PF_{lvq}(\boldsymbol{y})} \right)^2}, \tag{6}$$

where γ is a parameter, and $PF_{lvq}(\boldsymbol{y})$ is given by Equation (4).

Since the smallness of PF expresses the degree of standard and is non-negative real number, a lower control limit does not exist. Since PF value of an anomaly data shows a far bigger value than PF value of a normal data, it can be helpful tool for visualization of an anomaly data by checking the series of PF_{lvq} (Fig.2).

3 Experimental

3.1 Experimental Settings

We confirm the validity of the proposed method using artificial data. Fig.3 shows the artificial data set used in the experiment. Generally, although the time series of each variable are displayed in the control chart, the scatter diagram was displayed in order to make it legible here. In fig.3, square point shapes (□) show samples of normal data. Round point shapes (◯) show samples of anomaly data. Triangular point shapes (△) show samples of outlier data that are used for confirmation of the effectiveness of the proposed method.

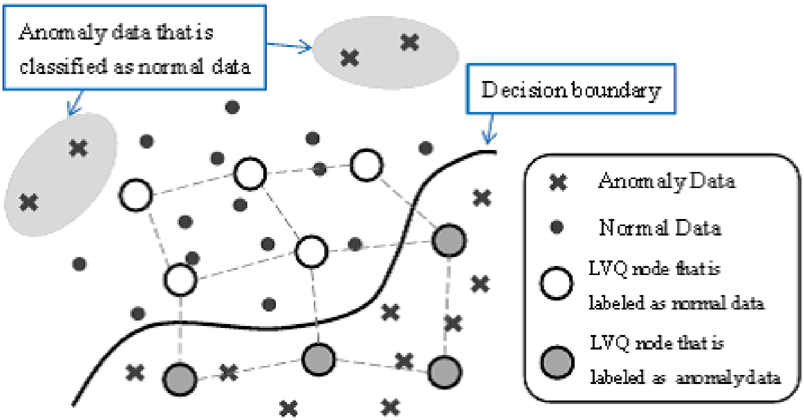

Fig. 1. Schematic diagram of the relation between LVQ node and data set

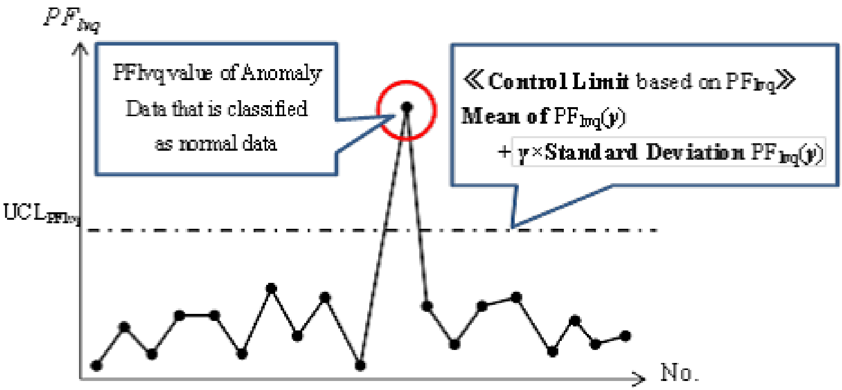

Fig. 2. Schematic diagram of constructed control chart by proposed method

Here, we generated 1000 samples of normal data set based on true distribution

$$p(x) = \frac{1}{(2\pi)^{d/2}\det(\boldsymbol{\Sigma})^{1/2}} \exp\left(-\frac{1}{2}(\boldsymbol{x}-\boldsymbol{\mu})^T \boldsymbol{\Sigma}^{-1}(\boldsymbol{x}-\boldsymbol{\mu})\right), \tag{7}$$

where, d is dimension of data set, $\boldsymbol{\Sigma}$ is covariance matrix and $\boldsymbol{\mu}$ is mean vector. And, we generated 300 samples of anomaly data set based on true distribution

$$p(x_1) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left(-\frac{1}{2\sigma^2}(x_1-2)^2\right), \tag{8}$$

$$p(x_2|x_1) = \frac{1}{\sqrt{2\pi\rho^2}} \exp\left(-\frac{1}{2\rho^2}\left|x_2 - \left\{-0.3(x_1-2)^2 - 5\right\}\right|^2\right), \tag{9}$$

where, ρ and σ are standard deviations. Table.1 shows parameter settings used in data generation.

Coordinates of outlier data are shown as (x_1, x_2)= (-5,6), (0,7), (5,6), (6,-2), (0,-3). Initial states of LVQ nodes are acquired by learning algorithm of k-nearest neighbor. Arrangement of nodes is optimized using the learning algorithm of LVQ3. Table.2 shows parameter settings used in experiment.

Table 1. Parameter settings used in data generation

Parameters	
d	2
Σ	$\begin{pmatrix} 4 & 0 \\ 0 & 1 \end{pmatrix}$
$\boldsymbol{\mu}$	(2,2)
σ	1.4
ρ	0.5

Table 2. Parameter settings used in experiment

Parameters of LVQ	
The number of nodes	30
The number of iterations	100000
Learning rate	0.1
Window size	0.3
Proportion of move for correct vectors	0.1
Parameters of PF	
α	1
β	1
γ	3

3.2 Experimental Result

In this chapter, the validity of the proposed method is confirmed from an experimental result. Fig.4 shows the learning result of LVQ3 for experimental artificial data set. From this result, it was confirmed that discernment of a few unclustered data labeled as outlier is not realized although discernment of clustered data with nonlinearity labeled as anomaly was realized by only using LVQ. Fig. 5 shows the result of the outlier value detection using the proposing method to classified data as normal data by only using of LVQ. Five data of the center of the control chart showing in Fig. 5 are outliers which are not discriminable in LVQ. Since these data had exceeded the control limit defined by equation (5), it

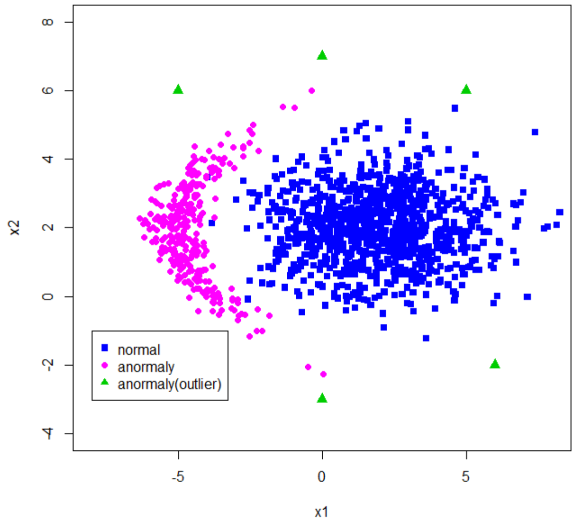

Fig. 3. Artificial data sets

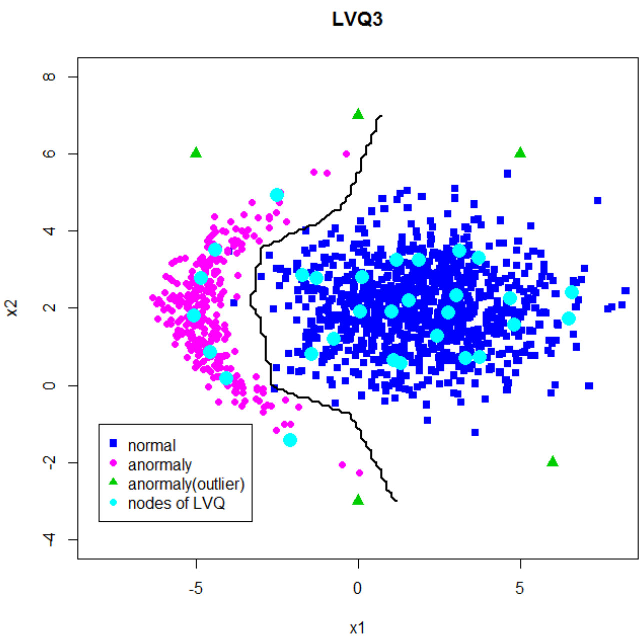

Fig. 4. Learning result of LVQ3 and acquired decision bounderly

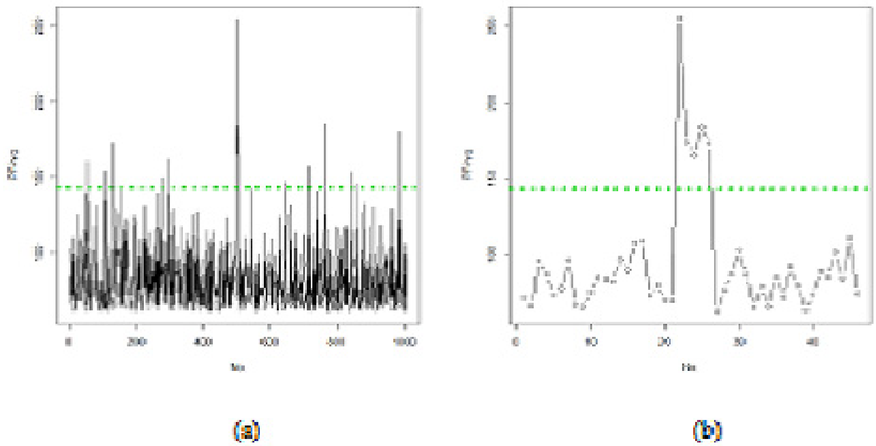

Fig. 5. Control Chart caluculated by proposed method. (a) shows control chart of all data set. (b) shows control chart of outlier data.

has been detected as an outlier data by the proposed method. It was shown that proposed method can detect outlier data which was not able to be classified by only using LVQ as anomaly data.

3.3 Discussion

The problem of anomaly value detection unsolvable only by discernment of the class of an abnormal value and the class of a normal value was solved by calculating PF on LVQ. Since the usual PF calculates based on the distance between all the data, computational complexity increases rapidly with the increase in data. The explosion in computational complexity of PF has been avoided by our proposal of calculating PF on LVQ. In the experiment, the data with a big error of the normal class might be judged to be an unusual class. Suitable parameter setting for reducing such a type 1 error need to be examined in future studies.

4 Conclusion

In this study, we propose the methodology of anomaly data visualization and detection using hybrid model of LVQ and PF. And, we experimented to confirm its effectiveness. The anomaly data assigned to the class of the normal data was able to be displayed as an outlier on the control chart by calculation of PF on LVQ. The proposed model realized the robust discernment and visualization of the anomaly data that have complex distribution by small computational complexity.

Acknowledgments. This work was supported by JSPS KAKENHI Grant Number 24710173.

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Train Ride Simulation Using Assist Strap Device

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Abstract. This paper describes an approach to implementing a train ride simulation system that is aimed at application to museum exhibits. A novel device was developed that presents the vehicle motion to a user in the standing state through the floor and assist strap. The prototype device has two degrees of freedom that enable horizontal translation of the floor and the strap. Using the device, a control algorithm to represent the lateral acceleration and rolling was investigated. An experiment proved that the change of track curvature presented by the algorithm can be recognized by the subject.

Keywords: Train Ride Simulator, Motion Platform, Virtual Reality.

1 Introduction

Application of virtual reality (VR) technology to museum exhibits is expected to enhance the understanding of content by visitors, and many investigations on practical applications have been carried out [1]. In museums that deal with technological topics, there are many exhibits aimed at enabling visitors to understand the function and principle of a mechanical system. Even in traditional exhibits, such explanations have been given with best effect using not only schematic images but also interactive models that represent the essence of the mechanism. It is expected that VR technology will have a potential to improve such exhibits through intuitive, interactive, and realistic presentations.

The authors of this paper are interested in the presentation of the suspension mechanism of a train. Trains have mechanisms that attenuate the vibration and rolling motion of the train body, and differences in the mechanisms cause differences in the movements of the train body. Our aim is to give an intuitive explanation of these differences. In general, there are two types of suspension mechanisms for trains: one type merely consists of springs and dampers that block vibration from the truck, while the other type also has a swinging mechanism to tilt the body depending on the centrifugal force. The latter mechanism is quintessential for investigations toward improvement of the ride quality and can be a topic for explanation in museums that

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 189–197, 2013.

deal with trains and railways. Our research has attempted to apply VR technology to this topic.

There are many systems that present the rides of various vehicles and have been in practical use [2]. Most such systems are designed to present the motion of the vehicle while the user is seated. This style is suitable for simulations of automobiles and airplanes. However, in most cities the public modes of transportation, such as subways and buses, are frequently crowded, so people are often standing in the vehicle and holding an assist strap. In this style of riding, the contact between the human and the vehicle is localized to the floor and the strap. This means that the ride can be virtually presented by using an interface device that simulates only the floor and the strap. Of course, it is possible to represent the motion of the entire vehicle body using a motion base; however, this approach makes the system larger. Our study investigates another approach, with the interface limited to the floor and the strap, which enables a more compact implementation.

2 Assist Strap Device

When a person is standing and holding an assist strap while riding on a train, the person is in contact with the train at the floor and the strap. The motion of the train is recognized by the person through the motions of the contact points. Our research deals with the simplest implementation, which has only two degrees of freedom for horizontal translations of the floor and the strap. By using this interface, presentation of lateral and rolling motions of the train is investigated. A schematic image of the approach is shown in Fig. 1. The lateral motion is represented by translations of the floor and the strap in the same direction. Conversely, the rolling motion is represented by translations of the floor and the strap in opposite directions, which is an approximation because the distance between the floor and the strap changes.

Similar to the usual motion base system, our device is limited in the range of motion and cannot present a sustained lateral acceleration. It is necessary to substitute for lateral acceleration by leaning the user to exploit a component of gravity. For this method to work, it is necessary to provide an illusion of the rolling sensation that is different from the actual rolling motion. This illusion is realized through visual presentation of a scene that provides the visual cues for a sensation of self-motion. Generally, such a visual cue is more effective when the field of view of the image is larger.

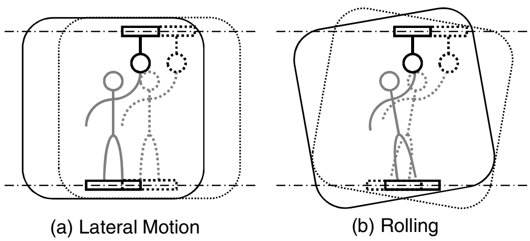


Fig. 1. Presentation of vehicle motions

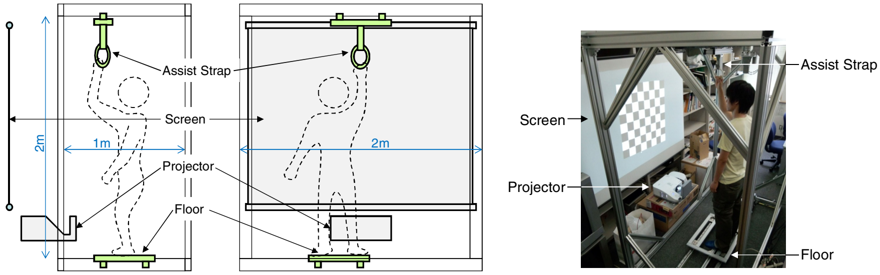


Fig. 2. Structure and implementation of device

Based on the discussion above, a ride simulation system that combines motion with a visual display was implemented (Fig. 2). The floor and the assist strap were actuated by AC servo motors (NX820AA-J10, Oriental Motor). The rotation of the motor shaft was converted into translational motion by means of a timing belt. The maximum continuous and peak output forces were 204 N and 612 N, respectively, and the maximum velocity was 0.78 m/s. The action of the motor was managed through a motion control interface (PEX-H741444V, Interface). The visual display was implemented by means of front projection using a projector of short focal length (NP-U310WJD, NEC) and liquid crystal shutter glasses (3D Vision Pro, nVIDIA). The motion of the user's eye position was tracked using a magnetic sensor (Fastrak, Polhemus).

In the control method described in the next section, it is assumed that the device is operated by commands with acceleration as the target value. Actually, the motion control interface accepts position and velocity targets but does not directly support acceleration control. To solve this problem, an algorithm was developed that computes the position and velocity targets from the acceleration target.

3 Presentation of Vehicle Motion

A method for presenting the motion of a vehicle by using the system was investigated.

3.1 Control Algorithm

As stated previously, it is impossible to present sustained acceleration by using only translational motion. Hence, it is necessary to replace the lateral acceleration with a component of gravity by leaning the user. This method has been known as wash-out control and is commonly used in ride simulation systems [2]. The difference between our implementation and the previous systems is that it presents motion through only the floor and the strap.

A person on a vehicle undergoes both gravitational and centrifugal accelerations (denoted by g and a, respectively) as shown in Fig. 3. The angle between the direction of the total acceleration and the direction of gravity is expressed as follows:

$$\theta = \tan^{-1}\left(\frac{a}{g}\right)$$

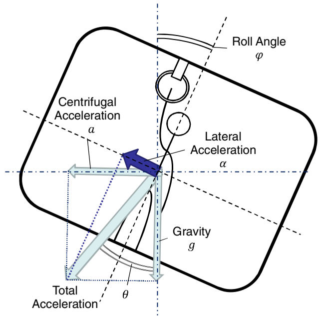


Fig. 3. Acceleration and gravity

If the vehicle is tilting by an angle φ, then the lateral component of the acceleration of the user is obtained as

$$\alpha = g\frac{\sin(\theta - \varphi)}{\cos(\theta)}$$

To represent this acceleration by the component of gravity alone, the leaning angle should be

$$\gamma_{1.0} = \sin^{-1}\left(\frac{\alpha}{g}\right)$$

Actually, a previous study suggested that the angle $\gamma_{1.0}$ causes an excessive sensation of lateral acceleration and that about 35% of α is sufficient for a realistic presentation [3]. Our system also employed this empirical parameter; hence,

$$\gamma_{0.35} = \sin^{-1}\left(\frac{0.35\alpha}{g}\right)$$

It is impossible to change the leaning angle instantly, since it takes time to move the mechanism. Thus, it is necessary to complement the lateral acceleration by using translational motion. The acceleration that must be imparted is computed as follows:

$$\beta_o = 0.35\alpha - g\sin(\gamma_{0.35})$$

Moreover, the translational acceleration causes a velocity, and so the motion must be decelerated, perhaps imperceptibly, after the leaning operation has been completed.

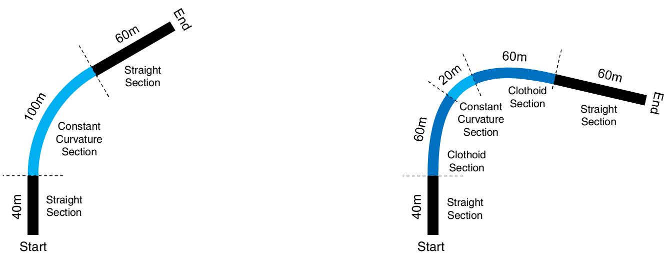
In our control algorithm, the control methods were defined on the basis of the respective states of control. In the wash-out state, the leaning operation and the generation of lateral acceleration are performed in parallel. So that the operation is completed within a given constant time T, the angular acceleration of the leaning, $\ddot{\gamma}$, was determined as follows:

$$\ddot{\gamma} = \begin{cases} 4\gamma_{0.35}/T^2 & (0 < t < T/2) \\ -4\gamma_{0.35}/T^2 & (T/2 < t < T) \end{cases}$$

In the deceleration state, the translational velocity is decreased by a constant deceleration of β_d= 0.05 m/s^2. Finally, in the wash-back state the translation of the mechanism is reduced to zero by a constant acceleration or deceleration of β_b= 0.01 m/s^2.

3.2 Discrimination of Curvature

Presentation of lateral acceleration such as that experienced while passing along a curved track was examined. In the experiment, two types of track were assumed: A) a track where a section of constant curvature is directly connected to straight sections, and B) a track where the curvature changes gradually according to an easement curve (Fig. 4). The easement curve was defined using a clothoid curve in which the curvature changes in proportion to the distance from the beginning of the section. The vehicle in this experiment does not have springs or dampers and follows the track faithfully. The velocity of the vehicle, v, is constant and the centrifugal acceleration at curvature L is calculated with $a = v^2 L$.



(a) Track A (b) Track B

Fig. 4. Track configuration

As stated above, a visual presentation is essential for successful wash-out operation. The user receives cues on the position and orientation of his or her body relative to the vehicle. In our implementation, it is supposed that the user is standing at the front window of the vehicle. The user can see the internal wall and window frame of the vehicle as well as the view outside the window (Fig. 5). Since the user moves relative to the visual display, the image on the display is updated depending on the position and orientation of the user.

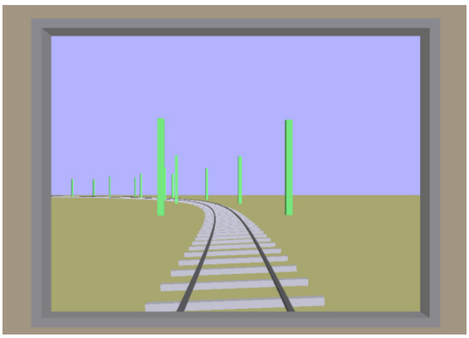
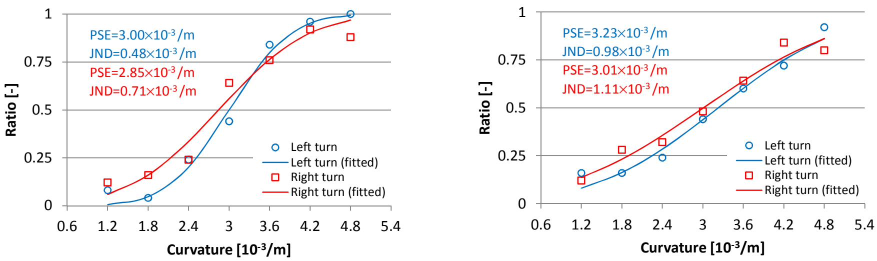


Fig. 5. Visual presentation

This experiment focused on the discrimination of curvature through the presentation of acceleration. A method of constant stimuli was employed. The standard stimulus was 3.0×10^{-3} m^{-1}, while the comparison stimuli represented changes from the standard stimulus by $\pm 1.8 \times 10^{-3}$ m^{-1} in steps of 0.6×10^{-3} m^{-1}. The velocity of the vehicle was 20 m/s (72 km/h); hence, the centrifugal acceleration due to the curvature was 1.2 ± 0.2 m/s^2. Each comparison was reported through a binary choice (i.e., larger or smaller). The curvature and the direction of curvature (i.e., left or right) were changed in random order. Each subject performed five sets of comparisons, or 70 comparisons in total. There were five subjects: three males and two females, ranging in age from 20s to 40s, all right-handed. Ear plugs and headphones playing white noise were used to eliminate auditory cues from the motors. The device was covered by a curtain to block outside light, and the glasses were hooded to restrict the field of view. Additionally, the subjects were asked to hold the assist strap with the left hand. The experiment was carried out using both track types.

The discrimination characteristics obtained from the experiment are shown in Fig. 6. Gaussian distribution functions were fitted to the data from the leftward and rightward curves, respectively. Moreover, the point of subjective equality (PSE) and the just noticeable difference (JND) were obtained. The results suggest that there is a difference in the perception of leftward and rightward curves. This was more apparent for track type A but was not statistically significant. It is conceivable that the difference in the direction of acceleration on leftward and rightward curves produced a difference in the user's posture and this affected the perceptions of vehicle motion and curvature.



(a) Track A (b) Track B

Fig. 6. Discrimination characteristics

4 Train Ride

As an experiment toward a museum exhibit, a ride simulation system that presents the motion of a train based on a mechanical model was implemented.

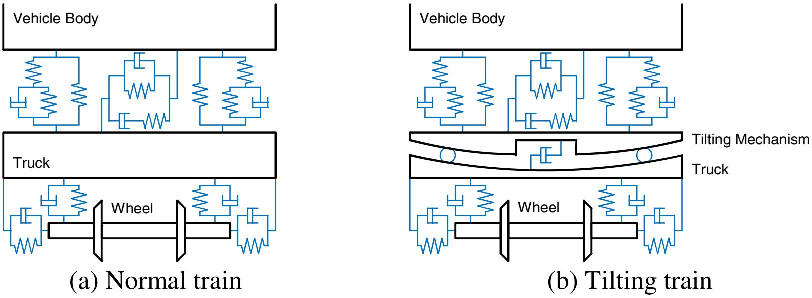


Fig. 7. Train models

4.1 Train Models

Two mechanical models of trains were implemented (Fig. 7). One is for a normal suspension mechanism that supports the train body using springs and dampers. The other is for a so-called tilting train that has an additional mechanism for tilting the body depending on the curvature of the track. The mechanical parameters in these models were taken from the literature [4], [5]. In this simulation the lateral motion of the wheels relative to the track was not considered, and the wheels were assumed to move smoothly along the track.

4.2 Evaluation

Discrimination between the train models was evaluated for subjects experiencing the ride for curved tracks. Three types of track were designed: A) a track without an easement curve and without cant, B) a track with an easement curve but without cant, and C) a track with an easement curve and cant. Schematic images of the tracks are shown in Fig. 8. The cant is the difference in height between two rails to realize a banked turn. All the tracks were the same in terms of the maximum curvature (4.0×10^{-3} m^{-1}) and the total length (490 m). Further, the velocity of the train was fixed at 20 m/s (72 km/h).

In each trial, the subject experienced two rides and indicated whether the train models for the rides were the same or different. The combinations of the models (2×2 models) and the types of the track (3 types) were changed in a random order. Each subject went through three sets of combinations, or 36 trials in total. There were four subjects: four males, ranging in age from 20s to 40s, all right-handed. As in the experiment of Section 3.2, auditory cues were eliminated by ear plugs and headphones playing white noise, outside light was obstructed by a curtain, and the field of view was restricted by a hood. Additionally, the subjects were asked to hold the assist strap with the left hand.

The proportion of correct answers for each track type is shown in Fig. 9. Generally, the proportion of correct answers was low. Even in the case of track type B, which

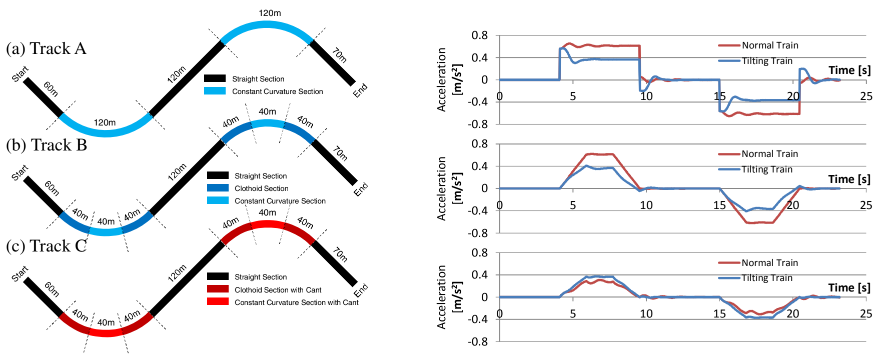


Fig. 8. Track configurations and lateral acceleration

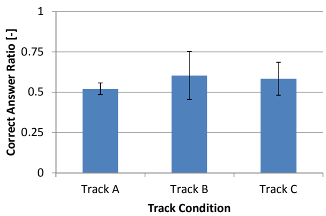


Fig. 9. Discrimination of train model

had the greatest proportion of correct answers, the difference of the proportion from 50% was not statistically confirmed ($p < 0.1$). The results suggest that the proportion increased in the order B > C > A, although the differences were not statistically significant ($p < 0.1$). From these results, it is deduced that our train ride system could not sufficiently represent the differences between the models. One reason for this is considered to be that the differences in lateral acceleration between the train models were relatively small, which made it difficult to recognize the features of the models.

5 Conclusion

This paper reported our investigation of a train ride system that presents the motion of a vehicle through the floor and the assist strap. The control methods known as washout and wash-back were introduced to represent sustained lateral accelerations. It was confirmed that the system is capable of presenting differences of curvature. However, it was difficult for subjects to discriminate between the train models. One of our future tasks will be to clarify the reason for this difficulty. How to present the roles of the other mechanical parts of the train is also of interest in our research. For example, the roles of springs and dampers in the suspension mechanism will be understood more intuitively through experiencing the effects of these parts.

Acknowledgement. This research was carried out as part of a project that is supported by the National Institute of Information and Communication Technology (NICT).

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A Precursory Look at Potential Interaction Objectives Affecting Flexible Robotic Cell Safety

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Abstract. With increased competitive challenges in the manufacturing sector, the need for operational excellence has led to an increased presence of robotics in factory settings. Traditionally, robotics in manufacturing has been relegated to routine and monotonous tasks performed in isolation to ensure human safety. Now, the advancements in robotics are encouraging a paradigm shift – human-robot collaboration. These new robotic systems are imbued with the ability to 1) perceive anomalies in work environments and to correct/workaround these deficiencies, 2) adapt to changes in workload by means of reconfiguring their layout in a facility, and 3) autonomously navigate factory floors. Although we would like to believe that these innate abilities of second-generation robotics allow for immediate implementation of human-robot collaboration on factory floors, the truth is that more research is required to ensure safety, analyze performance, and define standards. This paper explores potential interaction objectives for human-robot communication in flexible robotic cells.

Keywords: Robotic Cell Design, Industrial Human Robot Interaction, Safety, Human-Centered Design, Human-Robot Collaboration.

1 Introduction

On average, productivity in the US has increased by two percentage points each year from 1980 to 2008 [1]. During that same period of time, employment in the manufacturing field has fallen from 29% of US total workforce to 11% [2]. To increase annual productivity gains, manufacturers have minimized human resources and employed automated systems. Traditionally, automated machineries were employed to conduct routine and hazardous tasks and these systems have often led to the improvement of efficiency, productivity, quality and reliability. Discrete manufacturing has experienced much success with the use of industrial robots, which created work environments that took full of advantage of robot applications and their ability to enhance product quality and economic efficiency [3].

The work environment created to support traditional robotic systems placed humans in a supervisory role on the factory floor. Human handlers played an integral

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 198–206, 2013.

role working in tandem with these systems by monitoring routines and efficiency. The looming risks associated with safety prevented the close proximity interactions between robots and humans. In traditional robotic systems the main repositories of information pertaining to routines are the robots themselves. One of the main reasons for this fact is that humans tend to be easily overloaded and bored with the minutia of routines. This systematic setup perpetuates an information chasm between human and robot that is deeply ingrained in industrial standards for human-robot interaction (HRI). Compounding this situation is the fact that the allocation of work in manufacturing cells has traditionally been based on the performance or machinery-behavioral considerations [4]. The confinement of such planning methods relegates HRIs to an isolated, distant experience, where by the human is the last entity notified about actions or problems.

Modernization has seen the introduction of robotic systems which incorporate novel programming architectures that allow for flexible production operations. In such systems, multiple products can be made on a single production line or manufacturing cell. This enables some amount of intelligence and flexibility to be incorporated into the system along with improved efficiency, productivity, quality, and reliability [5]. However, the current robotic systems cannot satisfy the implementation requirements for these operations. Therefore, humans must be reintroduced to the factory floor as participants in human-robot collaborations (HRC) rather than as intruders in a robot's workspace. Behaviors attributed to humans in these systems are negated during optimizing of manufacturing system performance, as planners assume there is an existing information asymmetry due to humans lacking immediate information and the machinery possessing all the information for immediate decision making on routine operations.

The new paradigm requires the robot to be productive and safe while collaborating with humans in shared workspaces. Collaborative tasks between robot and humans takes place, typically, in operations with low product volume, and high product variation [6]. Humans in these systems are generally needed for their dexterity and ability to perceive and correct anomalies in the work environment. The novelty of such capabilities in humans is such that it has to be taught to robots within close proximity (for those machines that are state of the art) or by trial and error high-level programming. With the impending need for close proximity work environments, between humans and robots, the onus now shifts to robot designers.

2 Background and Related Work

Research in HRI risk assessment has identified many factors that could be hazardous to humans within a robot's workspace [7,3,8]. The derivation of these factors stems from four general areas, namely: robot self-awareness, robot self-reliance, human-robot dialog, and robot adaptability [9]. Robot self-awareness is important as the robot should be able to realize its limitations, thereby setting the stage for human-robot dialog. Without robot self-awareness, issues such as robot operating space, human awareness, and robot safeguards become of paramount importance [8,9]. Self-reliance in a robotic system refers to the system's ability to undertake routines with limited to no human influence or presence. This innate ability reduces cognitive loads for human workers, which allows them to conduct other tasks. Another area of concern for robot designers is human-robot dialog. Typically, robotic systems communicate via warnings, making communication a very one-sided affair. Communication in this setting has to be dual, and this requires a more cerebral experience, with a special focus on human cognitive loads. Finally, robot adaptability refers to ease of usage as well as its ability to change routines based on external demands. How easy it is for a robot to change its routines predetermines its frequency of use in small product volume environments.

Robotic systems in widespread usage today are generally designed to limit unsafe usage but not for continuous monitoring of humans in work areas, in an effort to avoid accidents [10,11]. These policies generally stymie the potential of HRC and render humans as intruders in the robot's workspace. The limiting of unsafe usage is accomplished mainly by human-robot segregation policies enacted by makers of these systems and government agencies charged with monitoring safety in the workplace [10,12]. This approach to safety has provided safety strategies related to fault avoidance, tolerance, and detection. Although segregation is one of the most common safety implementations, safety modes such as Shutdown, "Safe Operation", and "Safe Handling" have also been recommended. These modes would allow for a human to enter the robot's workspace, but the robot would not be performing at acceptable production rates.

Alternative approaches to ensure human safety have focused on high-level human-robot interaction and/or high-level robot independence with respect to performance measures [9]. In today's manufacturing environment, performance and productivity are paramount. Steinfeld et. al. [9] developed a model addressing safety and risk factors categorized as five basic areas: Navigation, Perception, Management, Manipulation and Social. This model serves as a starting point for HRI that does not force the robot to stop production in the presence of a human. Validation of the model's proposed areas and their impact on performance with a representative sample of factory workers could provide needed insight.

Defining metrics that balance the relations between safety and productivity are key attributes that must be guaranteed before widespread adoption can be realized in industrial settings [13,10,7]. Currently, the National Institute of Standards and Technology (NIST) along with the International Organization for Standardization (ISO) are working on technical specifications that will define collaborative workspaces with performance and safety in consideration. The proposed standard will be issued through ISO/TS 15066, and it will be a forerunner to the final standard that will be developed by NIST and the ISO [7]. However, the standard still tries to separate human from robot by its safety system guidelines that regulate "speed and separation". In the research area of HRI with professional service robotics, robots and humans work intimately with each other, in some cases with the human, knowingly, ceding the making of important decisions [14]. As is the nature of this field, industrial robotics and robotic researchers alike, take their cues from governmental agencies missing out on vital issues surrounding human-centered designs [15,16].

3 Theory Development /Conceptual Model

With advances in robotic technology, the concept of HRC will be implementable. The paradigm shift from “speed and separation” based HRI to HRC in shared workspaces requires modification of the factory floor, robot design, and teamwork dynamics. One major aspect of the team work dynamic is human’s perception of robots as dangerous and robots reaction to humans as intruders. Humans must perceived their robotic helpers as peers who can engage in an effort to jointly solve problems [17,16]. Robots must be able to perform safely at acceptable rates within the presence of humans. The HRC should learn from effective human-human collaborations.

Feedback and communication are key in human-human collaborations [16]. They could also play an integral part in HRC. For different interaction roles, there are different levels of communication needs. With the traditional separation of humans and robots, the immediate feedback and synchronous communication during interactions is rare and less often implemented. As the spatial proximity decreases with HRC, communication needs should transition from unidirectional to bidirectional communication. Communication can foster effective collaborations.

Unidirectional communication has been the focus of traditional robotic system designers. The segregation policies enacted for safety on factory floors allowed one-way communication, where the robot did not have to consider human counterparts in a shared workspace. In unidirectional communication systems, information provided by the robot is based on warnings or problematic situations that require human intervention. Independently working robots in these situations are only forced to shut down once one or more of their warning sensors are triggered. In most cases, these sensors do not make the robot aware of its surroundings but only of a problem that could potentially affect its operation. This type of communication only supports productivity and safety when the workspace is not shared among humans and robots. If the robot is unable to perceive a human and adapt its functions, the workspace becomes potentially deadly for the human. Information asymmetry abounds in these systems, and it will take a truly different means for communication channels between robot and humans to be fully developed.

Most advanced robotic systems have developed semi-directional communication channels. Although in these situations human robot segregation still is dominant, for compliance with strict safety guidelines and policies, robots are now able to process basic information about humans in a workspace. For example, in prototypes being tested by NIST and their partners, based on the ISO/TS 15066 standard, the robots use laser scanners to measure speed and position of the human to pause the robot during a routine operation[12,18,19]. In such a situation, the system is only able to perceive the presence of a human as a potential safety hazard. In an effort to avoid violating safety guidelines, the robot slows its pace of operation or stops entirely, all dependent on human-robot spatial proximity. This is a major step in the right direction; however, it does not support a highly productive HRC environment. Even if the robot slows its pace to continue some range of operation, sufficient information for a collaborative environment is not relayed to the human. For example, an alarm may sound indicating a safety hazard, which has a negative effect on performance and on the human’s perception of the work area. In these circumstances safety trumps performance of the entire system; therefore, truly collaborative relationships can never be realized (see Fig. 1).

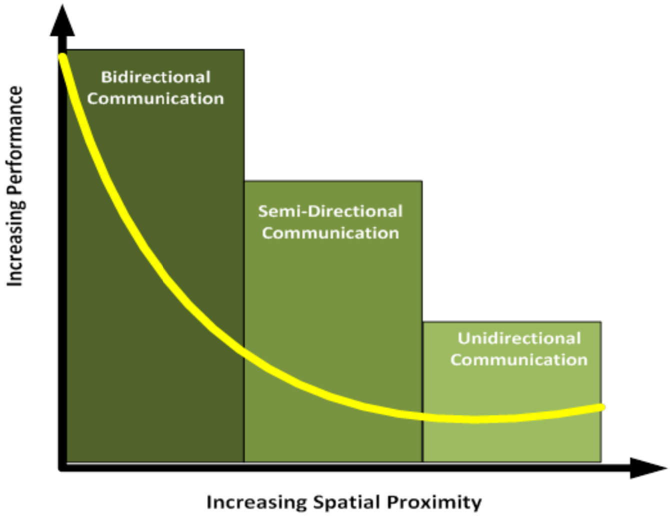

Fig. 1. Communication's Impact: HRC Spatial Proximity & System Performance

Robots, if they are to be considered peers, need to be able to possess the ability of bidirectional communication. The abilities of perception, comprehension, and communication are critical to collaboration, safety and performance. To guide future research and development we have created a model to support bidirectional communication among the human and the robot. The effectiveness of this communication relies on its ability to build and maintain awareness for both parties. From the literature review, five key types of awareness – Physical, Task, Interaction, Human Capability, and Robot Capability - are hypothesized (see Fig. 2).

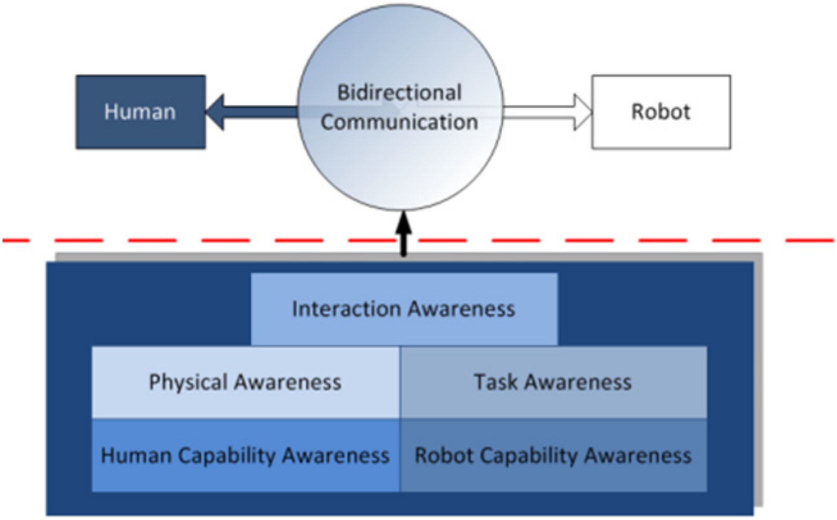

Fig. 2. Human-Robot Bidirectional Communication Model

These areas can be explained in the following manner:

- *Physical Awareness* – refers to the human's and robot's capabilities to discern and perceive physical abilities and limitations in the shared workplace [20,21]. Each should be aware of their collaborator's workspace, number of moving parts, position of moving parts, and range of motion. This extends current models that achieve and ensure safety via robot shutdown and pause modes and sacrifices productivity, establishing safety and productive objectives [6]. Bidirectional communication must rely on the exchange of information related to current movements, transitions, and future movements within the shared workspace. The means of communication that takes place here could be tactile, verbal and visual in nature [22]. By utilizing these three sensorial facets the aim should be for the robot or the human to make contact with each other in an effort to commence communication in an intuitive modus. Therefore, there should be no excess cognitive loads placed on human or robot for communication to transpire [10,8]. Adhering to this guideline should positively impact the human's perception of HRCs.
- *Task Awareness* – refers to the human's and robot's ability to understand both roles and the coordination that is required in the work setting for each task. This aspect has great impact on productivity and cognitive workload objectives. Robots need to track task attributes in the presence of human collaborators and share the information effectively. Allowing the robot to track and communicate task progress and hindrances could support continuous dialog between the partners [6,8,21]. In addition, modifications to improve operations could be implemented quicker with early detection and communication.
- *Interaction Awareness* – refers to the human's and robot's ability to interact and communicate in various modalities [21,9]. The types of interaction must accommodate the collaboration with consideration of the environment, task, and human abilities [7,8,20]. This aspect should be flexible, as dependent factors shift during production [3]. Safety is the main objective for this aspect with a focus on methods and techniques for communication.
- *Human Capability Awareness* – refers to the human's and robot's ability to determine the human's ability to collaborate [8]. Mental/cognitive overload of human peers within a particular workspace is a major safety concern that has been studied [10]. Robots can monitor human physiological characteristics for stress and fatigue and use this information to develop trends and patterns [6,7,22]. The information could also be used to adjust the work mode of the robot. By equipping the robot with this trait, the behavioral patterns of the robot can be tailored for specific human peers and recommend breaks accordingly. This aspect would support safety and productivity objectives.
- *Robot Capability Awareness* – refers to the robot's effective communication of its capabilities and limitations to the human. To improve the human's perception of and ability to collaborate with the robot, knowledge of the robot's capabilities is needed [6,9]. These capabilities are related to features, functions, power levels,

malfunctions, safety triggers, and help tools [3,22]. With human-human collaborations, understanding your partner's strengths and weaknesses allow for better partnerships [3,8]. Once the robot has an awareness of its own limitations then it can and should communicate this to its human partner.

Advancement of HRC in factory settings will rely on research and design developments in each of the discussed areas. For each, future work is suggested to focus on the information content, interface usability, and communication modes to achieve the highlighted objectives.

4 Conclusion and Discussion

The need and desire for improved performance has stemmed from many different factors, including globalization, competition, and the economy. HRC is one of the most promising methods for enhancing performance. This type of HRC being advocated is not the traditional – complete separation of humans and robots and supervisory control – type dynamic. With the desire for increased performance based on HRC, where humans and robots work in close proximity as partners, there is a more fundamental approach that needs to be taken to the building and commissioning of robotic systems. The new vision to have humans and robots share the same workspace – side-by-side or face-to-face – will mean that they will have to be imbued with the basic capabilities for human communication [3]. This will have significant impact to existing manufacturing paradigms; impact will extend well beyond floor layout changes that enhance human-robot segregation policies. It will also affect the design, implementation, evaluation, and maintenance of these systems. Robot design and implementation will have to be enhanced via the development of suitable mechanical structures and physical characteristics of the type most prominently found in professional services robotic systems.

Industrial robotic systems currently available on the market do not meet the safety and reliability criterion for close proximity HRC relationships due to the impaired viewpoints they possess [6]. Robots are only part of the solution. The humans in these partnerships will also have to be considered. Humans have been trained to perceive the robots as dangerous and a safety threat. Any human entering the robot workspace is labeled an intruder and this can be found in the literature being used as the basis for the next generation of standards [23,7,3]. For effective HRC, humans and robots must work together as partners. Scholtz [16] confirms that this partnership would require dialog, asking questions of each other, and jointly accomplishing tasks. Many researchers have focused on what the robot needs to know about the human and methods to obtain that information. Information that the human needs to know about the robot is of a similar nature to that needed by the robot itself about the human. As the industry moves from work area designs that completely segregate the humans and robots there should be a shift of attention and priority that ranks performance just as high as safety.

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An Intelligent Interactive Home Care System: An MPLS-Based Community Cloud

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Abstract. In recent years, scholarly research on the use of new technology in healthcare has intensified. Some of the main challenges identified in the literature include the integration of dissimilar signaling systems, network barriers such as bandwidth allocation, battery life in wireless devices, the security and privacy protection associated with data transmission using public network and the user friendliness of the systems, among others. The aim of this paper is to address some of the above concerns by introducing a secure, multiplatform network system capable of providing the dynamic bandwidth allocation required for today's home healthcare services. It incorporates a user friendly interface by introducing a unique instrument integrated with the community cloud arrangement to provide a more robust system to address the needs of multiple stakeholders.

Keywords: Cloud Computing, MPLS, ICT, RFID, Virtualization, Smart Sensors, Network Capable Application Processor.

1 Introduction

Despite the fact that cloud computing is a post-Web 2.0 technology, the concept is rooted in earlier technologies such as Grid Computing [1] and distributed computing architecture [2] such as Peer-to-Peer (P2P) architecture. Essentially, cloud computing is a Service Oriented Architecture (SOA) and multiplatform structure, which is integrated with Web 2.0 technology (as its user interface) that provides a layer of abstraction in the form of virtualization.

According to U.S National Institute of Standards and Technology (NIST), cloud computing is a convenient method for gaining on-demand network access to a shared pool of configurable resources (see http://www.nist.gov/itl/cloud/index.cfm). This technology promotes the availability of computing resources (e.g., networks, servers, storage, applications and services) by providing high level abstraction to its users [3]. It allows the customer (users or programs) to request computing resources across the network as needed, anywhere and at any time [4]. This model is composed of five essential characteristics, three service models and four deployment models. The main characteristics of cloud computing are: a) on-demand self-service, b) broad network access in form of support for thin or thick client platforms (e.g., laptops, mobile

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 207–216, 2013.

phones, iPads, PDAs, servers), c) resource pooling in the form of dynamic allocation of computing resources such as storage, processing, memory, network bandwidth and virtual machines, d) loose coupling structures that provide rapid elasticity or scalability, and e) monitoring services that measure their usage and utilizations [3].

The service model of cloud computing, is composed of three main categories or layers: Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). While the SaaS layer provides customers with the capability to use the provider's applications through thin client interfaces such as Web 2.0 based applications, it hides the underlying infrastructure (e.g., server, operating systems, storage and so on) and its location from its ultimate users. Or, as argued by [5], the service oriented characteristic of the cloud abstracts the details of inner implementation. The second layer, or PaaS, supports a set of application programs that interface the cloud applications [5]. It provides a development platform to organizations in the form of programming languages, business logics and management tools for deploying custom designed applications. PaaS hides the implementation details of the underlying infrastructure. Finally, the IaaS layer—also referred to as Hardware as a Service (HaaS)—provides infrastructure support such as processing capabilities, storage, network hardware and connectivity, servers and other computing essentials. While the customers do not manage or control these resources, they may gain limited control of them upon request.

The deployment models of cloud computing include the private cloud (which operates solely for an organization) and the community cloud, which is shared by several organizations by supporting their shared requirements, policies, security concerns and/or compliance considerations. Two other deployment models include the public and hybrid clouds. While the former is a type of cloud offered by a provider to the general public, the latter is a combination of two or more cloud models [3]. The aim of this study is to integrate networked smart sensors into a cloud computing system by providing a user friendly web-based interface to stakeholders (e.g., patients, doctors, nurses, caregivers, pharmacies, central control systems, management, etc.). Providing such a ubiquitous support for home healthcare systems integrated with cloud computing serves as a means to reduce the cost of operations. From the implementation point of view, this study uses an RFID/WiFi converter to extend the signal reach of RIFD devices to a longer distance as well as make it possible for the system to handle RFID data in form of IP packets suitable for transmission over the community cloud. The network infrastructure introduced in this study is designed to securely carry out mission critical data such as patients' health care data with a higher transmission rate while complying with the quality of service offered by the cloud computing and supported by the Next Generation IP Networks.

2 Sensor-Based Home Healthcare System

The world's aging population is growing, so too is the number of people who need post-surgery home care coordination. In addition, post-operative and health care related to children require effective monitoring systems at home. As such there is a need for an effective system that is not only capable of managing the increasing number of home healthcare service clients but also responds to their needs in a timely manner, regardless of the their location. For example, according to the Health Council of Canada, most seniors in Canada live at home and would like to remain there as long as possible. This includes seniors who are in need of immediate health care support. According to various healthcare reports, the costs of home health care in future are expected to rise relative to the heath sector [6, 7]. As such, Information and Communication Technology (ICT) can be leveraged to contribute to better quality care as well as to help maintain the cost reductions of such a large scale operation.

As noted by [8], healthcare and social welfare systems are being re-engineered globally. Across both the developed and developing world governments are recognizing the need to maintain or reduce costs and to increase the efficiency and effectiveness of healthcare delivery and management. ICTs provide a foundation for transforming supportive apparatuses to meet the complex structure of today's healthcare systems including caring for the patient in the so-called "Hospital without Walls" [8]. As such, the future delivery of healthcare will clearly be predicted on two factors: 1) the provision of ICT infrastructure; and 2) the availability of healthcare and other professionals who are able to utilize such infrastructure [9] as a means of delivering patient care and health promotion in an effective and efficient manner.

Such a holistic approach is best described in the course of its impact on improved healthcare delivery in the form of home care services. This involves an assessment of the role of new technologies in enhancing both efficiency and effectiveness for all stakeholders [9]. The aim of this study is to incorporate wireless network smart sensors through some popular home care applications with a community cloud in a secure manner, as required by today's advanced health arrangements.

2.1 Smart Sensors

In the context of this study, a smart sensor is defined as a low-power, integrated microprocessor circuit that is not only capable of measuring healthcare related tasks with higher precision and accuracy, but it is also capable of communicating wirelessly with other components in an IP-based network. Smart sensors are devices which have been designed using IEEE 1451 (Smart Transducer Interface Standards) family standards for distributed systems integrated with network capable application processor (NCAP). With these, one can access any sensors or actuators in the 1451-based network wirelessly (or wired), independent of the underlying physical NCAP [10].

This paper aims to address some of these concerns by introducing a secure, two-way interactive communications between a centralized community cloud and other stakeholders, including the patients.

2.2 The Home Care Application

The cloud-based home care system of this study is implemented in two main parts: the actual home care system and the MPLS cloud implementation, which will be discussed in the next section.

We consider four major home care applications as a means of implementing an intelligent home care system through the setup of a smart sensor network system in a simulation environment. For simplicity, we limit our application to an RFID-based electrocardiogram (ECG or EKC) for real-time monitoring of electrical and muscular functions of a patient's heart conditions, an RFID-based medication intake box, and two other RFID applications for measuring the patient's blood pressure and body temperature (see Figure 1). This system can be expanded to any other application adhering to IEEE 1451 standards.

At the heart of this system there is a Home Care Controller (HCC) (see Figure 1 part C) which is a virtualized monitoring system connected to the home sensor network and controlled by a centralized home care monitoring system. In this arrangement, smart sensors are implemented as Near Field Communication (NFC) RFID devices composed of sensors with RFID tags, RFID readers and the HCC system.

2.3 The HCC System

The entire home care system is primarily initiated and controlled through a menu driven, user-friendly application. The application running in this system (see Figure 1 part A and B) activates one of the existing RFID readers as desired. The actual activation task, in terms of the signaling processing, is done by a device called a RFID/WiFi (see Figure 1, part C) converter which is wirelessly connected to the controller. As the name indicates, an RFID/WiFi device converts WiFi signals into RFID signals understood by the respective RFID reader and vice versa—it converts RFID signals received from an RFID reader into WiFi signals for further processing in the HCC system. This device is also used as a means of extending the range of RFID signals within a home care unit.

HCC, among others, contains a database for storing collected data locally for further processing. One of the important tasks of such processing is to compare data against preset criteria. For example, if an abnormal activity is detected the system triggers an alert in the form of a warning message displayed on the HCC's monitor, a wave-based buzzer (noise free) is attached to the patient's body or bed and an SMS is sent to the caregiver as well to the centralized monitoring system.

In addition, data stored on a local database can be redirected to the centralized monitoring system for storage into the home care centralized database system (see Figure 1). Further processes might include performing complex calculations and generating web-ready results which can be sent to the respective caregivers via any IP-enabled devices such as an iPhone. As shown in Figure 1 our home care system is a wireless access point/home router connected to cloud by the means of a high speed Internet connection (e.g., cable modem or similar technologies compatible with IEEE 802.11b/g/n, IEEE 802.3/3u (fast Ethernet with auto-negotiation) and IEEE 802.3az (energy efficient Ethernet)) which in turn is connected to IaaS provider's customer edge (CE) router (see also Figure 2). Both HCC and RFID/WiFi are using private IP addresses mainly for security purposes. In addition, two other measures are implemented to protect our home care system. The first measure is to password protect the system and the second measure is to register the home router's IP address with the provider's CE router so that only authorized IP packets can pass through the CE router. The latter is done through auto-negotiation of WLAN router.

Finally, using collaborative Web 2.0 technology [11], in the case of an emergency, our HCC system is capable not only capable of data sharing with other systems within the community cloud but also it capable of two-way, secure web-based voice and video communication between the patient and/or caregiver and the remote centralized control management system.

2.4 The Home Care Applications

One of the biggest challenges for seniors and other patients resting at home is timely medication intake. Many patients forget to take their medication and cannot recall or remember when, how many or what pills to take, which may lead to complications and health issues [12]. The home care system of this study offers a medication box, equipped with small drawers. Attached to the medication box there is an RFID reader that receives signals from sensors attached to each compartment of the box with a sensing panel door. When the panel door for the assigned daily medication is opened and the pills are taken, a green signal is sent to the HCC controller through the reader; based on the preset criteria, an alert, as described above, is sent out.

An RFID-based sensing blood pressure device is attached to patient's wrist. The RFID reader sends the collected to our HCC via the RFID/WiFi converter. The results will be saved in a local database for further processing. In the case of an emergency, an alert will be sent to the caregiver and other stakeholders. In the same manner the patient's body temperature can be measured (via gastrointestinal, forehead, oral, aural means, etc.) so that the RFID temperature reader receives signals from the temperature sensors and this information can redirect relevant data to the HCC system as described above. Heart disease is one of the most important areas in terms of citizens' health and the cost of operation it implies. A Holter monitoring system was selected for the purpose of recording a patient's ECG (or EKG). The Holter system is essentially an RFID-based ECG monitoring system in which the electrical sensing recorders are attached to patient's body and then the collected data is read by an NFC reader. The process of collecting electrical signal is initiated by the HCC system. Like other RFID measuring equipment, the accuracy of the collected data is a crucial step in providing proper healthcare advice and services. In the case of ECG applications, the sampling rate of electrical signals is the most important factor regarding the quality of waveform data. In addition, the network infrastructure should support the quality of service and reliability of data transmitted over the network to a remote centralized monitoring system. The network should also be able to support the bandwidth required for this purpose since real-time ECG data collection demands significant bandwidth. Finally, the speed of the network should be fast enough to support ECG palpitations so that in the case of an emergency, an immediate alert could be sent to the caregiver.

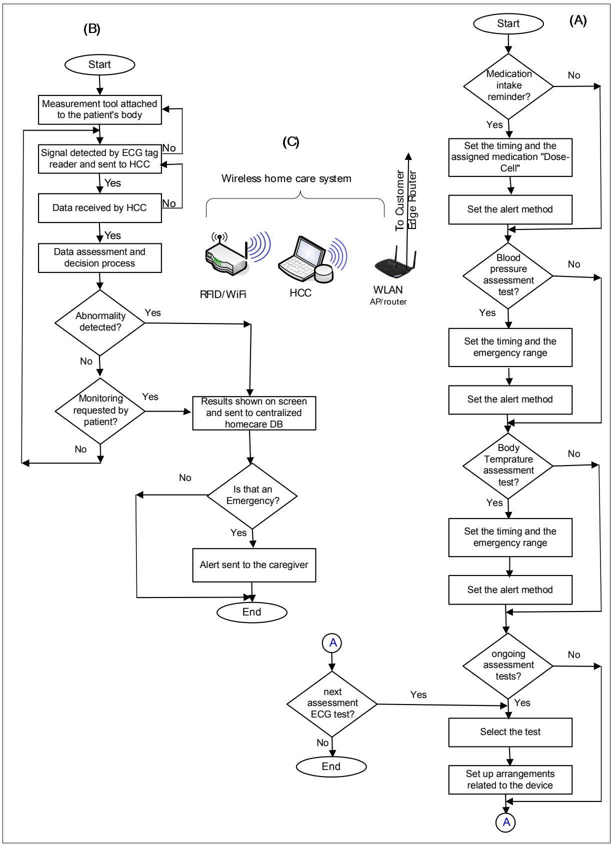

Fig. 1. The Home care controller system

3 MPLS and the Community Cloud

3.1 Network Virtualization

Virtualization is often anchored with cloud computing regardless of its models of implementation (e.g., public, private, community or hybrid cloud). In the context of cloud computing, virtualization is the ability to provide multi-tenant logical cloud services resources from multiple and different physical resources. Virtualization can be implemented at the infrastructural, platform, or software levels. It is often underpinned by the ability to provide a layer of abstraction via the grouping of physical resources to reduce costs and to form a cloud. It can exist in parts or throughout the entire IT stack from server, storage, and service to network virtualization [14] suitable for sensitive data transmission as our home care system. This study implements a type of network virtualization by deploying virtual routing and forwarding (VRF) commonly used in Multi-Protocol Label Switching (MPLS) which allows multiple instances of routing tables to coexist within the same router [14].

3.2 MPLS Cloud

MPLS is a tunneling protocol for secure real-time data transmission over a public network. Mechanisms used in this arrangement increase network security by eliminating the need for encryption and authentication [14]. MPLS offers advanced security features suitable for our home care model. These features include network speed, traffic engineering, quality of service (QoS), Virtual Private Network (VPN) and resiliency. Resiliency in an IP network is centered on the MPLS-based [15] cloud in order to achieve fault tolerance against failures of the network nodes (see Figure 2). Other capabilities of this arrangement include its traffic engineering capabilities and the availability of various classes of services (CoS). These services together offer the required QoS as demanded by highly sensitive networks such as those in healthcare.

VPN is implemented by the means of label distribution protocol. The label distribution protocol, as explained by MPLS, has the ability to reserve network resources for traffic flows. This is a particularly important feature for real-time application such as our home care control system. It also speeds up data transmission by the means of label exchange by routers on the path. Traffic engineering is a useful feature for on-demand high quality network traffic. This extended feature offered by MPLS is executed through a protocol known as resource reservation protocol or RSVP (RFC 3473). This feature allows for better control over network traffic, particularly when sudden variations in traffic patterns and heavy load are traversing the network. Three major components of an MPLS network are: Labels, Ingress/Egress routers and core Label Switching Routers (LSRs) called also Provider Edge (PE) routers. Packets entering into an MPLS cloud are assigned labels. These labels are used as a means of packet delivery and they replace the traditional IP address-based packet delivery. In other words, this system hides the path of IP packets traveling within an MPLS cloud.

Figure 2 shows the implementation of the MPLS cloud within our community cloud. As shown in the figure, an Ingress router is directly connected to the router to deliver health data, also called a customer edge (CE) router. A CE router is any legacy non-MPLS IP router such as BGP or OSPF router. IP packets from CE routers enter into an Ingress router. An Ingress router is essentially an LSR router which is placed on the edge of our MPLS cloud. This router selects the best path within an MPLS network. Then it pushes (injects) a label into each packet entered into the MPLS cloud. The labeled packets are then sent to the selected core LSR router(s). The core LSR router then swaps the old label of each packet with a new label. In this arrangement the core LSR routers are label swappers. Swapping is done as a means of increased security. When the packet reaches the other edge of network, it enters into another edge router called an Egress router. The Egress router then pops (removes) the label and delivers the IP packets to the connected CE router (e.g., the router connected to database server). It is important to note that edge routers are capable of both push and pop operations (see figure 2).

As depicted in Figure 2, core SLR routers are connected in a meshed topology to provide multi-path options as a means of fault tolerance and load balancing for routing traffic from source to destination. It is important to note that MPLS is supported by IPv6.

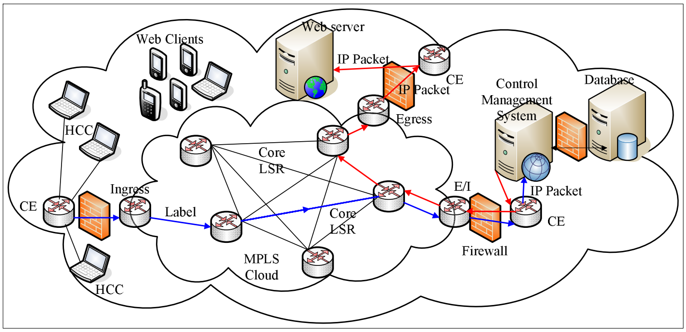

Fig. 2. An MPLS Community Cloud Legend: CE= Customer Edge router, HCC= Home Care Controller, E/I= Egress/Ingress

3.3 Data Processing and Presentation

Our network design, as depicted in the above figure, consists of a community cloud and an inner cloud which is the provider's IaaS MPLS-based backbone.

Data from our home care controller (HCC) systems enters the CE router in the form of IP packets. Firewalls are set up between each CE router and their neighboring Ingress/Egress routers. The reason for such a setup is that while data are secured within the MPLS cloud, they are vulnerable to malicious activities outside this environment. To secure the traffic we implemented firewalls in four main entries as depicted in Figure 2. Home healthcare data, from their collection to the resultant web documents on the clients' IP devices, go through nine distinguished yet interrelated steps as shown in Figure 2. In the first step, the CE router passes data to its nearest Ingress router. This router pushes a label (step 2) on the arriving IP packets and then forwards them to a neighboring core LSR router. After label swapping on the core LSR routers (step 3), packets arrive at the Egress/Ingress (E/I) router. The Egress router removes the label (step 4) and forwards the IP packets to the CE router that is connected to our centralized home care control management system (administrative) which in turn is connected to our centralized backend database server.

Authorized queries are forwarded to the database. In step 5, our database system responds to client queries in XML format packaged into IP datagrams. IP packets are then sent to a CE router connected to our monitoring server and from there they are forwarded to the E/I router. As a receiver, this router is now acting as an Ingress router, which pushes labels into IP packets (step 6). These packets are then forwarded to an LSR core router. The LSR core routers on the path swap labels with new values (step 7). The final destination of XML data within our MPLS cloud is an Egress router. After the pop operation (step 8) of the labels, IP packets are sent to the nearest CE router connected to our web server. This server is a virtualized multi-tenant web server capable of providing support to multiple applications and/or servers as a single system thus providing a more secure and robust topology than a legacy non-virtualized server. One key point in this arrangement is to hide the availability of multiple servers from the outside world [14]. The web server sends collected data in the form of web documents (step 9) to clients requesting the data by the means of a secure HTTPS protocol. Personal health applications allow their users to store a wide variety of personal health information and data ranging from medical conditions and test results to medications and allergies [9]. In this arrangement, clients are any IP enabled devices with authorized access to healthcare data (e.g., ECG data). The system is also capable of two-way, web-based secure video communication between HCC and the home care control management system.

One of the main drawbacks of the implemented virtualized network is its high demand on WAN link for a real time/on-demand data delivery. In this context, the network virtualization and MPLS are both bandwidth demanding applications not suitable for slow WAN link connections. In addition when the number of HCC systems attached to this system increases the demand on network bandwidth will increase significantly.

4 Conclusion

In this study we presented an intelligent home care service using a centralized monitoring system to incorporate a healthcare system into a community cloud shared by multiple parties. Our innovative home care cloud is a centralized system which offers various controls and alarm mechanisms designed to react responsively in emergencies. Using Web 2.0 technology, the user-friendly interface is capable of mentoring multiple patients simultaneously and reporting their health conditions to doctors, nurses and caregivers, as requested.

The contribution of this study is the implementation of a home care system that is fast and more reliable. It offers a flexible data routing mechanism in the form of traffic engineering, and provides the quality of service required by healthcare applications. It also offers a secure environment via MPLS protocols for transmitting medical records over public infrastructure. Smart sensors implemented in this system use RFID signals incorporated with the advanced features of wireless IP network. We proposed an interactive, menu-driven home care system called HCC in which the application running on this system controls the wireless sensor network and redirects information to a centralized location for further processes. In addition, the outcome of such processes can be sent simultaneously to multiple stakeholders if required. Finally, our system uses the virtualization features of cloud computing to dynamically expand the home care nodes to help reduce the cost of public healthcare systems. Another advantage of using an MPLS-based community cloud is its ability to integrate IPv6. However, the limitation of this system is its dependency on medical devices attached to wireless sensor networks. Improper installation of RFID devices and/or problems with faulty signals may cause problems when locating the root of functional problem. Therefore, testing the medical equipment is a vital task in the successful implementation of this system. It is also required that caregivers have appropriate ICT skills and training when engaging with the system's interfaces.

Acknowledgement. The author appreciates the assistance of Parisa Lak. Parisa's knowledge in the field of healthcare management has greatly contributed to this study.

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An Improvement of Disaster Information System for Local Residents

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Abstract. It has been pointed out that when people lack the information needed in the event of a disaster, such as a disastrous earthquake, this could lead to social chaos, including unwanted rumors and outrages, or could disrupt rescue and relief activities. In our prior study, we established a service infrastructure with an autonomous wireless network, aiming at providing services to collect and deliver disaster information. The system consists of many small sub systems. An authorized user can register information using one of the sub systems that is working correctly. Asynchronously, they search another sub system via wireless network, and then they communicate to each other in order to exchange information they have. As a result, the information will be shared within a wide area by those processes like a bucket brigade. In this study, we improved and extended the system so that it may meet more nearly actually.

Keywords: earthquake, disaster victims, distributed autonomous system, wireless network.

1 Introduction

In the event of a disaster, such as a disastrous earthquake, information provision is effective in preventing chaos at the scene. Therefore, timely and accurate information collection and delivery services are essential [3][4].

In Japan, by law in principle, self-help or mutual assistance is required immediately after a disaster, and local residents are required to make judgments for action on their own. Although disaster information systems are gradually being organized at the municipal level, actual emergency evacuation areas and essential information for local citizens are still not sufficiently ready for provision at this stage [5]. These services allow prompt rescue and relief activities and appropriate information delivery to local residents. Thus, it is urgent to establish a system to enable these services. The systems proposed so far are ones with Internet or mobile phone connections or with ad-hoc wireless LAN networks [6][7]. We call such systems communication channel dependent systems, which require communication channels or establish communication channels between clients and servers via an ad-hoc network. From the perspective of

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 217–222, 2013.

an information service, such systems that accumulate information in PDAs and send it via an ad-hoc network when a communication channel is established are also regarded as communication channel dependent systems.

There are two issues of concern regarding this system: 1) the system is not available until a communication channel is established, and 2) as users access the server to gain information, the intense access may lower server performance or cause communication channel congestion. In prior study, we would like to propose an approach to resolve these issues. As it is difficult to generalize the situations of earthquake disasters, we set the following assumptions: (a) assuming a strong earthquake of approximate magnitude 7 in a residential area, (b) all the lifelines including electricity and communication channels stopped functioning, (c) lines for land phones and mobiles are congested and not working, and (d) the proposed system (hereafter called “the system”) can be preliminarily placed.

2 Method

In order to resolve the above issues, we placed servers, which store information, closed to users in prior study [1][2]. By doing this, the system can run without a communication channel established, and the service can be continuously provided even with a narrow bandwidth. Since disaster information system users, such as local residents, shelter authorities, rescue and relief crews, and municipal employees are diverse and geographically dispersed, multiple servers are required to meet the condition in which servers must be placed close to users. Each server must hold information and be synchronized with each other. Also, they must independently run, communicate with each other, and dynamically detect others in case some are damaged in a disaster.

The service infrastructure consists of many small sub-systems. Each of these systems independently provides information collection and delivery services. Also, these sub-systems can autonomously work together with other sub-systems to exchange information. By appropriately allocating sub-systems within a region, regional information is continuously shared, which can solve the issue of information shortages in a disaster. We adopted general consumer hardware products that are supposed to work approximately 72 hours with batteries. Though each hardware product itself is not robust, they are all independent so even if some of them are damaged, they do not affect others. Also, as it is allowed to dynamically add sub-systems, damaged ones can be easily replaced to immediately recover the entire service.

The network configuration of this system is illustrated in Figure 1. The system is formed by a group of small servers (hereafter called nodes) with server abilities and dynamic communication functions. Each node can function as a web server and allows clients (e.g. PCs and PDA) to connect to register or browse information. Nodes also detect others within the communication range to synchronize information. With these functions, the system can still work as an integrated unit even when part of the hardware is damaged in a disaster. Figure 2 illustrates the hardware configuration of the nodes. We selected only devices that can function approximately 72 hours with either dry-cell or rechargeable batteries. In addition, dedicated PCs can be equipped with server functions for information entries. This means that users can initiate the registration of information even if no communication channels are established.

However, in previous studies, there were still some issues such as:

a) The synchronization of the information was often delayed,

b) The distance between nodes with a vertical interval which can be communicated is short.

This study improves the following points:

a) Improvement of the node detection logic and the information synchronizing logic,

b) Using two types (vertical no directivity and horizontal directivity, wide directivity) of antenna in order to be fit to our target area.

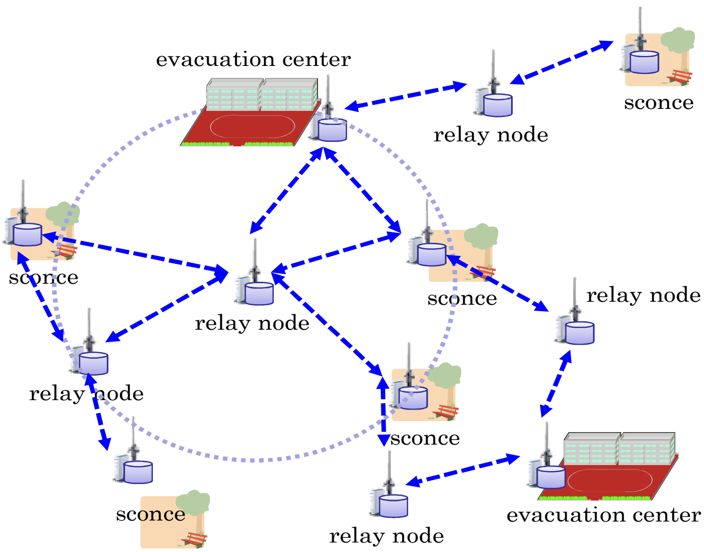

Fig. 1. Whole image of the system: all nodes search another sub system, and then they communicate to each other in order to exchange information they had

3 Result

By the first improvement, the delay in the synchronization of the information was decreased.

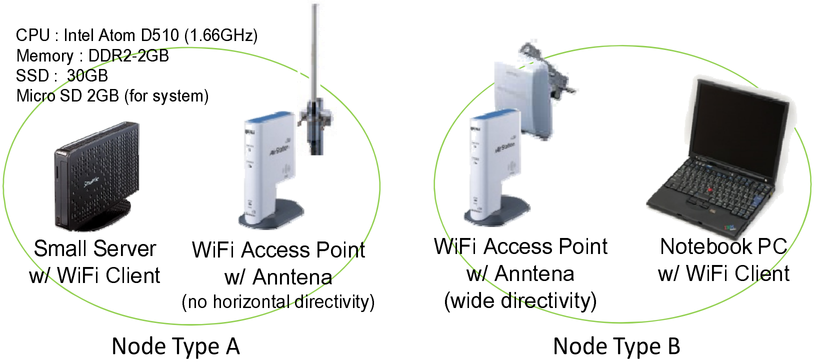

Fig. 2. Elements of the nodes

Node Detection Method

Each node executes the following procedures by a timer process in every minute.

1. The node scans APs (: Access Points) in range, and makes a list of available APs. Then the node selects a suitable AP (: Access Point) using an ESSID filter pattern and the connection history list.
2. The node connects to the selected AP. Then a server connected to the AP via Ethernet, gives IP address to the Wi-Fi client of the node (Figure 3).

The node calculates the IP address of the server from the given address of Wi-Fi client. Then the node executes synchronization program with the server.

The node disconnects from the AP, after the synchronization program finished.

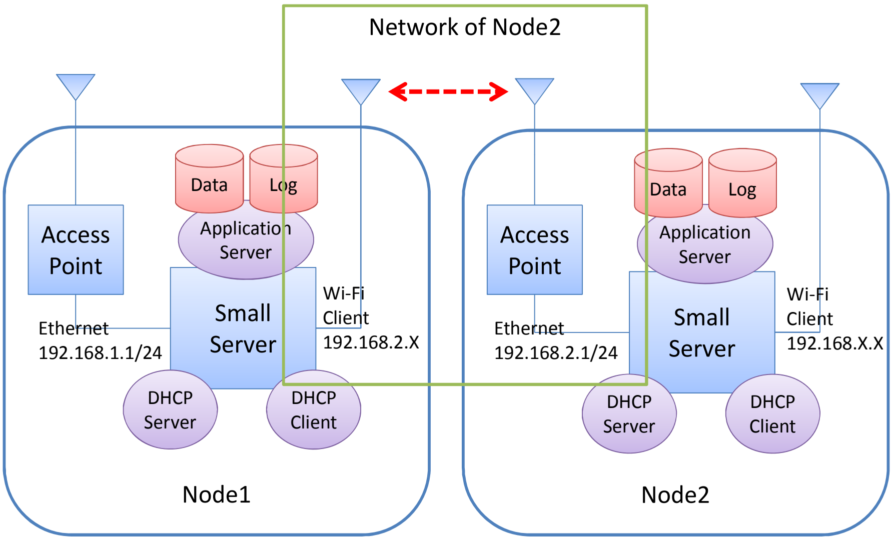

Fig. 3. Network between the nodes

Data Synchronization Method

Applications on the server such as registration of someone's safety, update the database table using special driver. The driver updates both of data and log tables. The log table contains node id, sequence number, operation type (create/update/delete), table name, update time and the data.

Synchronization process is a client server model. The client makes list of the holding data as array of the range of the sequence numbers and the node name. Then the client sends the list to the server. The server finds and sends back the data that the client doesn't have. The server executes same process as the client, if the list sent by the client contains entries the server doesn't hold. While this process is executing, the client becomes a server.

By the second improvement, the system will become the form of being suitable for use in actual evacuation areas. Moreover, in a simulation, it carries out as a result for the layout planning of nodes, by using three-dimensional (instead of two-dimensional) geography data and taking the characteristic of antennas (Figure 4) into consideration.

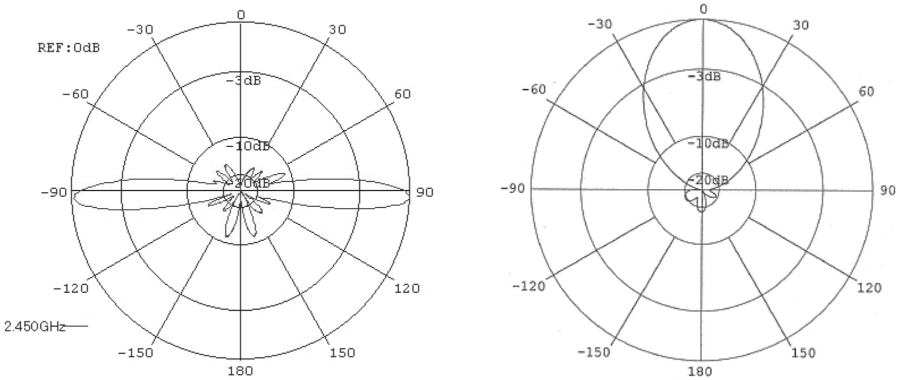

Fig. 4. Vertical no directivity and horizontal directivity, wide directivity

4 Conclusion

By those improvements, the system will be more practical. At present, the functions are well working in the field. However, only four nodes were evaluated at actual evacuation area. In order to deploy the system for real disaster, evaluations are needed with more nodes at wider actual evacuation area.

5 Future Work

The global image of the project including this research consists of three copies of the embodiment; of 1) service infrastructure construction, 2) service application construction, and 3) service employment. The service infrastructure was able to be built in the process to this research.

From now on, it is necessary to put power into construction of the service application advanced in parallel. Service application is roughly divided and has a function of information registration and an information inspection. It is necessary to perform design and evaluation of an application model and a user interface, considering the realizable employment method of service and taking the following points into consideration.

- Information registration can be performed efficiently in an actual shelter etc.
- Follow that there is no stress in the information which a disaster victim needs, and stick.
- The information which a relief person needs can be collected.

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Improving the Flexibility of In-Vehicle Infotainment Systems by the Smart Management of GUI-Application Binding Related Information

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Abstract. This paper introduces an approach to build a new system application addressing the smart management of binding related information for in-vehicle infotainment systems. The system application is based on a client-server model using Web technologies and provides message oriented middleware to drive bidirectional GUI-Application communication. Additionally, it also allows GUI-Application binding at runtime and supports the same GUI to be bound with the applications located on different devices. The result shows that this approach improved the reusability and the adaptability of binding related information, and also increased the flexibility and the scalability of IVI systems.

Keywords: in-vehicle infotainment, GUI-Application binding, SOA, runtime binding, WebSocket, middleware.

1 Introduction

In comparison to foretime, today's car is not only the means of transportation, but is also integrated with interactive computational environment allowing an internet connection and multifarious applications e.g. Browser and social community. This interactive computational environment, also called in-vehicle infotainment (IVI) system [1], is an integration of in-car information system and entertainment system. The in-car information system consists of the applications which are responsible for the exchange of information between the user and the vehicle as well as the traffic environment, e.g. a navigation program. The entertainment system provides the user entertainment related functionalities, such as radio or media player.

The graphical interactive components of IVI systems can be described abstractly with three layers: graphical user interface (GUI) layer, application layer and additional middleware layer binding the GUI and application components. Figure 1 shows a classic IVI system based on the above described layers and the event-driven communication among them. The GUI layer can be specified by the presentation elements which define the visible information (e.g., layout, color,

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position or text) as well as the control logic elements driving the screen transition. The application layer can be described by its business logic and functional units (e.g. C++ functions and Java methods) which implement the functional capabilities of applications. In the development process of today's automotive software products [2], it is common that the GUI and the application components of IVI systems are developed separately and then bound together at development stage using a middleware layer which is also called binding layer. Currently, the binding layer is based on a data pool, an event observer and an event handler. The data pool is implemented as a list of variables which can be changed by the events initialized by the GUI and the application. The event observer monitors the data pool and catches the change events of the data pool. If a change event of the data pool is caught by the event observer, the event handler will drive the update of the GUI. In the development of automotive software products, HMI specifications and applications of IVI systems are individual in each target product. Therefore, the binding related information, which is exchanged between the GUI and the application, is dependent on binary data whose name and value are product- and manufacturer-specific. Therefore, the binding related implementation of previous development cannot be directly used for present and future development. The major part of the middleware needs to be re-implemented for each new project and this reimplementation leads to additional development cost, as well.

The reason for this low flexibility is the lack of a mechanism which can automatically adapt binding related information in the middleware layer each time there are updated requirements. There is still no generic solution for how to increase system flexibility by improving the reusability and adaptability of such information. To face the above mentioned issue, this paper introduces an approach to build a new system application addressing smart management of binding related information for IVI systems. The objective of the system application is to support the runtime GUI-Application binding and also binding a common GUI with applications of different implementations, platforms and devices. If these objectives can be reached, the flexibility of GUI-Application binding for IVI systems will be improved, and the development time and costs of IVI systems will be reduced.

2 Related Work

In this section, we introduce several approaches which are related to GUI-Application binding and were already used in the automotive domain.

The EB Guide [3] is a development environment for the model-driven HMI (human-machine-interface) development of IVI systems. Within the EB Guide, the events are used to drive the transition of views linked to state charts. The data-binding is realized with the aid of a data pool implemented as properties of widgets. The property value of a widget can be changed by events initialized by the GUI and the application.

Another well-known development tool for modeling and generating the HMI of IVI systems is CGI Studio [4]. Courier is the interaction framework used

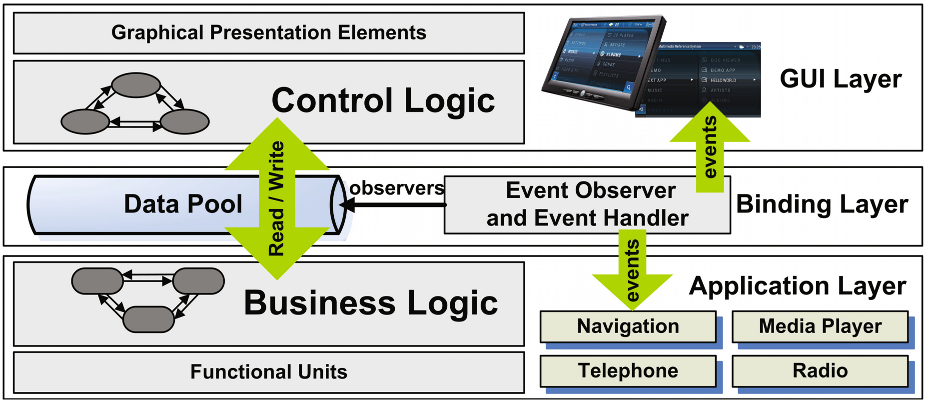

Fig. 1. GUI-Application binding of a classic IVI system

within CGI Studio and focuses on message handling and data binding with the application. This framework implements Model-View-Control architecture pattern.

To formally define the API for IVI systems, GENIVI Alliance[1] published a framework called Franca [5]. The core of this framework is Franca IDL, which is a formally-defined and textual interface description language (IDL). In Franca, an API can be declared by three basic elements: attributes, methods and broadcasts. The dynamic behavior of interfaces is described by using contracts, which are based on protocol state machines.

A flexible in-vehicle HMI architecture based on Web technologies was developed in [6]. This approach provided functions being handled as a Web service. The HMI was implemented using HTML and JavaScript and rendered in the browser. This approach supported the integration of external devices in the form of plug-in services in IVI systems and generated the HMI for this service at runtime.

Addressing the semantic description of binding related information, [7] introduced an approach to generate the HMI for plug-in services from semantic descriptions. This approach was based on four layers: service implementation, service functionalities and API description, abstract HMI description and concrete HMI with generation rules. Compared with other solutions, this approach used ontology for the reuse of knowledge and provided higher machine readable description of binding related information.

3 Methodology for Identifying Solutions

Addressing the objectives defined in Section 1, we deduced those requirements which could improve the flexibility of GUI-Application binding and fulfill the

[1] http://www.genivi.org/

domain-specific requirements for developing IVI systems. After this, we purposed several solutions which fulfilled each requirement. Then, we identified the final solutions for each requirement regarding the dependency and conflicts among these solutions.

3.1 Requirements Elicitation

Figure 2 shows the technical requirements for building the new system application. The requirements are based on two top aspects: the flexibility aspect and the quality aspect, which are outlined as the roots of two trees. Its corresponding leaves are numbered from F1-7 and Q1-3.

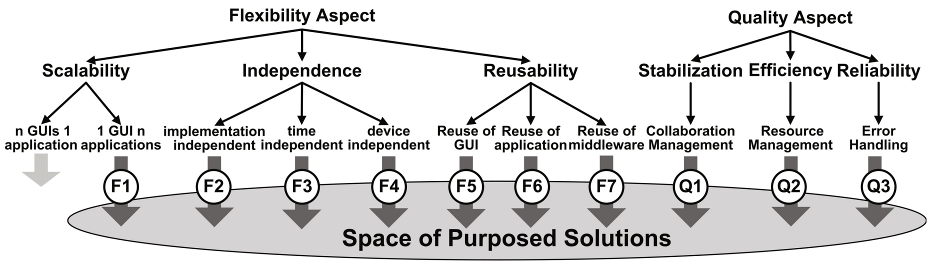

Fig. 2. Requirements elicitation

The flexibility aspect addresses the requirements for improving the scalability, independence and reusability for GUI-Application binding. In this context, scalability means that two types of extensions should be supported in an IVI system. The first extension allows generating GUIs from different design concepts for an application. In another extension, a GUI can be bound with multiple applications, which are located in different platforms or devices or are implemented differently. The requirement of independence can be described in three sub requirements. A full flexible GUI-Application binding should be independent of implementation (e.g., platform or programming language, the time when the binding happens, and device, on which the target GUI or application is located). Another important requirement of the flexibility aspects is the reusability which can be refined by the reuse of GUI, application and middleware.

Besides the flexibility aspect, how to keep continual stabilization, efficiency and reliability of IVI systems by improving its flexibility is also a challenge. Compared with mobile devices, the instable system behavior and the failures in the application and the GUI of IVI systems lead not only to low user experience but also to the user being distracted from driving, and can even cause accidents. For this purpose, a collaboration management which enables the stable collaboration among the components, especially by using a loosely coupled system architecture, is needed. In this paper, we concentrated only the requirement on efficiency under the same condition of hardware. The efficiency requirement of

IVI systems can be concreted as resource management e.g. thread assignment. Besides stabilization and efficiency, error handling is also required for a reliable system behavior.

3.2 Identifying Solutions

In our work, we have focused on binding multiple applications with the same GUI. Therefore, the requirement on generating multiple GUIs for a single application will not be considered in following work.

Solutions to Requirement F1, F2, F3, F5 and F6. The pre-condition for binding multiple applications to a common GUI (F1) as well as the reuse of GUI and applications (F5 and F6) is that these applications have the same abstraction but are implemented differently. This means that the APIs used to invoke these applications should be in a standard form. For independent implementation (F2), two of the most popular technologies service-oriented architecture (SOA) and object-oriented architecture (OOA) could be applied. A well-known example of OOA for middleware is CORBA [8], which is based mainly on a request-response mechanism. However, IVI systems prefer an asynchronous function invocation, which has more performance benefits in comparison to a synchronous function invocation. Compared with OOA, SOA has the benefit not only in implementation independence and loose coupling, but also in efficiency of function invocation with the aid of additional support for the asynchronous function invocation. For this reason, we have chosen the SOA to realize the independency of implementation. In order to enable the GUI-Application binding during the development time, and also at runtime (F3), the new system application must provide a mechanism supporting the GUI to be bound with a reference instead of binary data. The benefit of using a reference is that the binding can be executed after functions are being called. This also provides the possibility to swap the sources of applications under the same GUI at runtime. Based on the above described requirements, we chose Web service which allows application abstractions, supports the SOA and provides reference for function invocation at runtime.

Solutions to Requirement F4. For device independence, there are two possible technologies which could be applied in our work. The first possibility was the approach based on the server-client model. The idea behind this approach is to develop a structure supporting the GUI layer, the binding layer and the application layer located in different devices. Another possibility was to use MirrorLink which is also called Terminal Mode [9]. This solution supports mapping the GUI from mobile phones into IVI systems but does not provide any benefits for the other requirements. Therefore, we chose the server-client model with extension of Web technologies.

Solutions to Requirement F7. In order to improve the reusability of the middleware, it was anticipated that the binding layer can self adapt on new changes in the GUI layer and the application layers e.g. adding a new button or changing the source of application. Bidirectional communication, which is driven not only by the GUI, but also by the application, should be allowed to avoid the high manual reimplementation for new development requirements. Combined with F4, we chose WebSocket to realize the bidirectional communication.

Solutions to Requirement Q1. Collaboration management is an indispensable requirement for loose coupled systems. There should be a definition on how these independent components communicate with each other. The possibility was using either a central message broker or standalone solution, which requires an additional message mechanism for every component. This leads to high implementation and maintenance cost. For this reason, the central message broker was more suitable for our solution.

Solutions to Requirement Q2. To improve the resource management of a server-client model, which bases principally on a synchronous function invocation, we would extend the server-client model with additional asynchronous function invocation such as callback functionality in our solution.

Solutions to Requirement Q3. There existed two possibilities of the conception of error handling: developing a separate component for error handling or integrating error handling in the participants of message communication. For the purpose of reducing system complexity, we preferred to integrate error handling in the components which initialize message communication.

4 System Design

Based on the identified solutions, we used a top-down method to design the system application. Figure 3 shows the system architecture at runtime.

First, we defined a layer model based on the GUI layer, the binding layer and the application layer. Based on the server-client model, the GUI layer was refined by the GUI client and the GUI server. The implementation of the GUI is located in a GUI server, loaded and rendered in a GUI client at runtime. The binding layer and the application layer respectively contain binding server and application server(s). The application server is a computational environment of a device, on which the applications and the Web services are located and invoked. Between the GUI client and the application server, the binding server processes the request from the client and invokes the Web service of the application server. The client and servers can be located in different devices or in the same device, e.g., the GUI client and server, as well as the binding server can be a part of IVI systems.

Second, we refined the components for each layer. The GUI was described by the control logic elements, the presentation elements and the GUI message handler. The control logic elements define the control logic e.g. the menu flow of

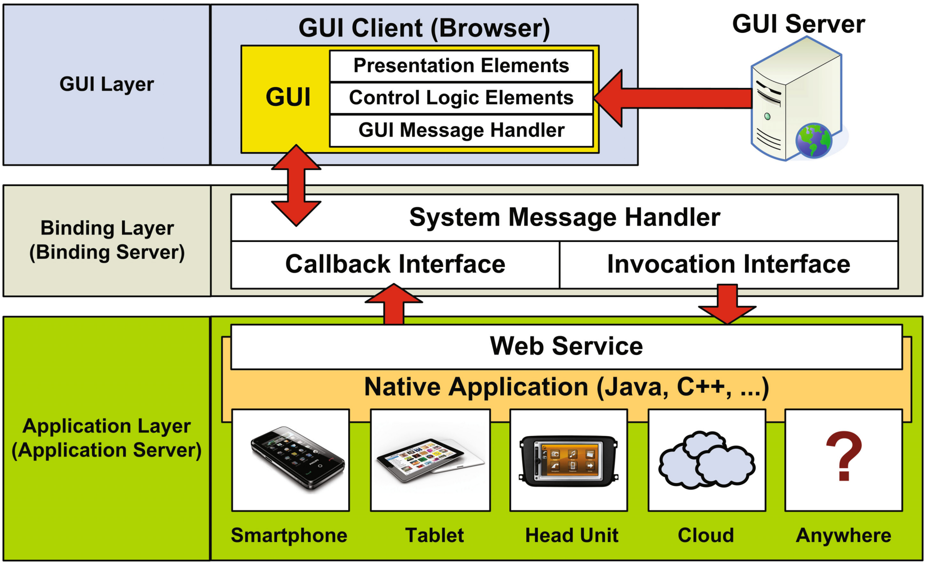

Fig. 3. System architecture of the developed system application

the GUI according to the user behavior. The presentation elements represent the presentation information e.g. color or position of widgets. Additionally, a GUI message handler was developed to handle the interaction-related message.

On the server side, we have also defined a message handler called server message handler. These two message handlers are the central components for the communication between GUI and application. They manage the following binding related information: the initialization object of communication, the content of communication and the target object of communication. This information was described in the form of a message with sender, content and receiver. Additionally, two types of interface were defined: invocation interface and callback interface. The application server provides Web service which abstracts the functional capabilities of the local applications. It can be located in a Smartphone, a Tablet, a Head Unit of car, in Cloud or anywhere, if the connection with the binding server is established.

In addition, we have defined three participants of message communication in GUI-Application binding: GUI, Web service and system service. The system service represents the basic functions of the operation system (OS) located on the binding server. Based on these three participants, we categorized the binding related messages in nine types and defined the routers for handling different message types (see Table 1). Initially, the messages which are initialized by user interaction via the GUI, are processed in the GUI message handler. If these messages are related to invoke a function of application or OS function, it will be forwarded to the system message handler. The system message handler has a mapping table, which helps to match the GUI events to the corresponding functions. Otherwise, the GUI message handler will directly update the target GUI element. The messages, which are initialized by a Web service or a system service and related to update the GUI, will be handled in the system message handler and then forwarded to the GUI message handler, which is responsible for updating the GUI. As our work focuses mainly on the message communication between GUI and application, the message communication between the application and the OS, as well as the intercommunication of the OS were not regarded in this paper.

Table 1. The routers for handling different message types

Requester	**Responder**	**Router for message handling**
GUI	GUI	GUI message handler
GUI	Web service	GUI message handler → system message handler
GUI	system service	GUI message handler → system message handler
Web service	GUI	system message handler → GUI message handler
Web service	Web service	-
Web service	system service	-
system service	GUI	system message handler → GUI message handler
system service	Web service	-
system service	system service	-

In this paper, three types of message casting were defined. In unicast, there is only one receiver, which can be a component of the GUI, the Web service and the system service. Multicast allows at least two receivers, but not all available components. In broadcast, all available components of the GUI, the Web service and the system service can receive the sent message.

Figure 4 shows the work flow of the GUI message handler. In the left figure, a GUI event was initialized by user interaction in the GUI logic control block. If this event is relevant for invoking a function, a message object based on the implementation language will be created and sent to the binding server. If this event is also related to an update of the GUI, the GUI message handler will send the message to the related GUI component(s) and perform decomposition, if it is necessary. On the other figure, the GUI message handler has received a message object from the system message handler located in the binding server. In this case, the GUI message handler is responsible for decomposing multicast or broadcast messages and for updating the target GUI component(s).

5 Prototype

Based on the developed system architecture (see Figure 3), we implemented a prototype in a Java platform. The presentation elements (style and layout) of the GUI were implemented using CSS and HTML5. The control logic elements

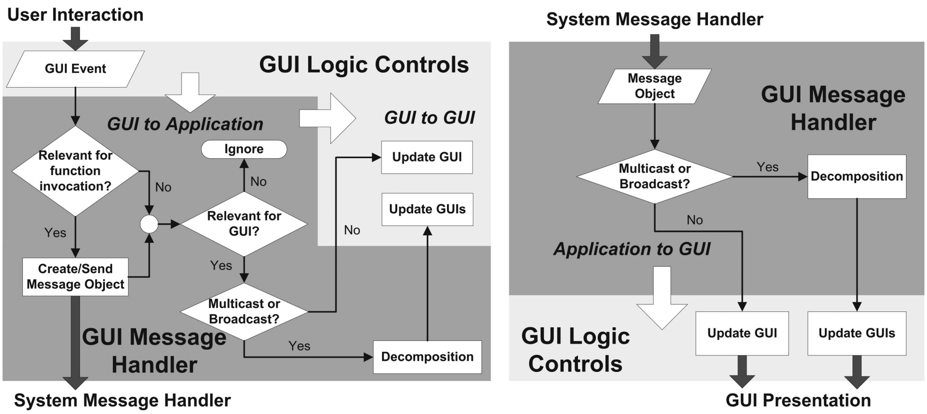

Fig. 4. Workflow of the GUI message handler

and the GUI message Handler were realized using JavaScript. The system message handler was implemented in servlet and used WebSocket to connect to the GUI message handler. Additionally, JSONObject was used for formalizing the messages. The callback interface and invocation interface connected with the Web service used a SOAP engine based on Axis 2.

To demonstrate the developed prototype, we implemented two media player applications using Java and C++ and named them AP1 and AP2. Additionally, we developed a simple GUI for the media player. Both applications were implemented in different algorithms but the common abstraction in the form of Web service interface was used. To evaluate our work, we defined the following criterions: (1). Is GUI-Application binding at runtime successful? (2). Is binding a common GUI with applications of different implementations, platforms and devices successful?

Based on above criterions, we have performed four tests (results are shown in Table 2). Device A and B were desktop PCs running Linux and device C was a Tablet running Windows 7. The following components were involved in testing: both applications AP1 and AP2, the binding server (BS), the GUI server (GS) as well as the GUI client (GC). We have combined these components into four groups and allocated them on the devices (see Table 2). In every test, we have successfully bound the GUI with applications at runtime and could flexibly swap

Table 2. Results of evaluation

Test Nr.	Device A	Device B	Device C	1. criterion	2. criterion
1	all components	-	-	Yes	Yes
2	AP1, AP2	BS, GS	GC	Yes	Yes
3	AP1, AP2	BS	GS, GC	Yes	Yes
4	AP1	BS, AP2	GS, G C	Yes	Yes

the sources of the applications under the GUI. The results show that our work enabled the GUI layer, the binding layer and the application layer located in separate devices. Additionally, our solution allowed not only a GUI-Application binding but also to change the source of applications at runtime.

6 Conclusion

In this paper, a new approach has been developed which addresses the smart management of binding related information for IVI systems. This approach was based on the solutions derived from the requirements on improving the flexibility and the requirements of automotive software products. On this basis, we have developed a system application which is able to bind the same GUI with multiple applications at run time, which were implemented in different programming languages, located in different devices and running on different platforms. The results show that our solution provided a high scalability of IVI systems at runtime. In our work, we have reached an improvement of the flexibility of GUI-Application binding for IVI systems by increasing the reusability and the adaptability of binding related information.

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Part II
Health and Quality of Life

Young Adult Health Promotion: Supporting Research Design with Eye-Tracking Methodologies

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Abstract. Despite increasing mental health problems among college undergraduate students, little work has been done to investigate factors that can improve health promotion among this population. To address this need we designed a research program that addresses health promotion toward young adults. In particular, we are interested in addressing mental health and risky health behaviors among college undergraduate students. The research reported in this study is the result of the first basic step in our research program.

Keywords: Computer-Mediated Communication (CMC), Online Persuasion, Eye-Tracking, Fixation, Involvement, Message Source, Young Adults, Health, Online Persuasion, Interpersonality Model.

1 Introduction

Since 2006, the percentage of college students with severe psychological problems has grown by 16%. According to recent surveys of campus counseling centers, depression and anxiety are the top two mental health problems among college students [6], and these conditions can have devastating consequences. "Indeed, the second leading cause of death among college students is suicide, which accounts for about 1,100 deaths per year on campuses …. The No. 1 killer is accidents, which include accidental overdoses and drinking and driving deaths, many of which might be linked to depression and anxiety." [3].

The increasing prevalence of psychological problems among college students calls for scientific investigation of factors that can improve their health. One way to do so is by improving the effectiveness of health promotion among college students. Health promotion is defined as "the art and science of helping people discover the synergies between their core passions and optimal health, enhancing their motivation to strive for optimal health, and supporting them in changing their lifestyle to move toward a state of optimal health." [12, p. iv]. By providing support, structure, and motivation toward better health, health promotion programs aim to enable people to "increase control over, and enable, their health" [19, p. 1]. In the past, many health promotion

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 235–244, 2013.

efforts emphasized communication via mass media, including television, radio, newspapers and magazines, and targeted media, including newsletters, booklets, and videos [5]. More recently, the Internet has provided numerous new tools for health promotion, including online communication, social media, and gaming apps [9].

We recently undertook a research program that addresses health promotion toward young adults, specifically investigating mental health and risky health behaviors among college undergraduate students. As discussed above, mental health problems among this group are increasing [17] and risky health behaviors, including overweight, smoking, drinking, and risky sex, are relatively high [16]. Yet little research in the area of health promotion has been conducted among young adults due, in part, to difficulty of overcoming competing distractions of academic, social, and sporting activities, as well as the transient nature of this population's living situations [16].

Our approach in this health promotion research program is to adapt an interpersonality model of online persuasion (hereafter referenced simply as *interpersonality model*) to the context of young adult health promotion. The interpersonality model was developed to predict and explain message receivers' tendencies toward complying with requests they receive via email [20, 21]. We anticipate that this model will provide theoretical direction for identifying factors that can affect young adults' intentions to visit a health-related website and to recommend such a website to their friends.

Previous research has shown that email has the capacity to be an effective tool for universities to promote student health [2]. Yet Internet sources of health-related information are known to generate relatively low levels of believability among young adults [10], and email may be inherently limited in promoting behavioral change for this reason. Our overarching goal in this research program is to identify means of enhancing effectiveness and improving consistency of email messaging in the context of health promotion to young adults.

This paper presents our initial experiences in developing a research design for an online experiment in young adult health promotion with support of an eye-tracking methodology. Research shows that eye-tracking data can provide a valuable source of information on how individuals experience and interact with information that is delivered online [4]. Thus, we argue that eye-tracking will be useful in meeting the objective to develop experimental treatments that are robust, potent, reflective of the research objectives, and free from spurious effects.

In the following sections we describe the theoretical background of the interpersonality model and the adaptations we made in developing a new research design. Additionally, we explain how we use eye tracking to test the impact of experimental treatments as well as other measures in our study.

2 Theoretical Background

2.1 Interpersonality Model

The interpersonality model presented in Figure 1 [21] proposes that message receivers evaluate characteristics of email in order to categorize whether the message is interpersonal, i.e., interactive communication between two or more interdependent people, or broadcast, i.e., non-interactive, one-way communication that typically is designed to address a mass audience. Email is capable of delivering interpersonal and broadcast messages, including broadcast messages that are intended to appear to be interpersonal in form. These latter messages are often referred to as spam, which message receivers are generally motivated to avoid [8].

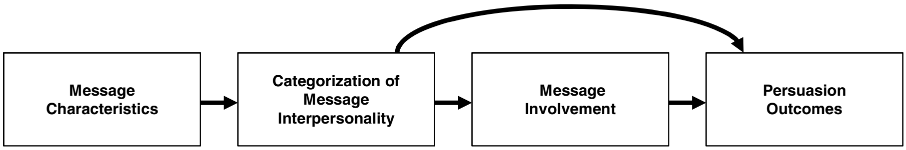

Fig. 1. Interpersonality Model of Online Persuasion

Interpersonality is determined by two factors: Message coherence, i.e., the perception that the sender's message is relevant to the receiver's situation, and personal feedback, i.e., the anticipation that the message receiver can respond to the message and receive a reply from the sender. The interpersonality model further predicts that higher message coherence and personal feedback will influence persuasion outcomes, increasing message receivers' compliance tendencies both directly and by increasing involvement with the message [21]. In the present study, we focus on two distinct persuasion outcomes: Intention by the message receiver to visit an online health resource and intention by the receiver to recommend the online health resource to a friend.

2.2 Message Source

Kwan et al. [10] find young adults access health-related information more from the Internet (79%) than from parents (66%) or health center medical staff (56%), yet young adults rank believability of health-related information accessed via the Internet to be lower than from either of these alternative sources. Viewed from an interpersonality model perspective, this observation suggests that the source of a health promotion message may be a key message characteristic that young adults use to categorize email messages. In this study, we are interested to see whether the reaction to messages is influenced by the similarity or differences in group membership between source and receiver. In other words, is compliance more likely to happen if the message source is the organization to which the receiver belongs?

2.3 Viewing Behavior

While we can see many things at a glance, we can attend to only one object at a time [4]. We typically attend to objects that we can see with our focal vision [7]. The area covered by our focal vision, however, is relatively small. Clear and colorful vision is facilitated by only the fovea region in our eyes, which contains a densely packed array of photo photosensitive receptors [7]. To compensate for the small size of focal vision, our eyes move rapidly and continuously in the visual field from one area to another, and visual information is processed only during the short period of times that our gaze is steady [14]. These periods of fixation provide a reliable indicator of attention and cognitive processing [13].

A recent study shows that fixation also can be used to measure cognitive effort and willingness to expend cognitive effort [4]. Djamasbi et al. [4] used the duration and frequency of fixation to measure the amount of effort expended when viewing a web page. Because reading a message requires cognitive processing and willingness to expend the necessary attention to comprehend it, we propose that fixations can serve as an effective measure to capture an individual's engagement and involvement with a CMC message. In the present study, viewing behavior can help us examine whether a message from a source belonging to the same organization that the receiver is a member (in-group) is likely to produce more involvement and behavioral intentions than a message from a source that belongs to an organization other than that of the receiver (out-group).

3 Research Method

We used the interpersonality model [20, 21] as a theoretical base for our investigations, using an online survey to collect participants' responses. We operationalized Message Characteristic as whether the message came from an organization to which the receiver belongs (in-group) or an organization that is not part of the receiver's community (out-group). Categorization of Message Interpersonality was operationalized using previously validated measures of message coherence and personal feedback [20]. Persuasion Outcome was operationalized using two measures: Intention to comply with the message, using a measure previously validated by Wilson and Djamasbi [20], and intention to recommend the message to a friend, using a measure created for the present study.

To examine the effect of message source we used two treatments, as in prior studies [20, 21] participants were randomly assigned to one of the two treatments. In both treatments participants were asked to read a text message that encouraged them to visit a health-related website and complete a self-assessment for mental issues such as depression and anxiety. After completing the task (reading the message) participants were asked to complete an online survey.

We used eye tracking to test for the presence of physiological evidence distinguishing the treatments in our study as a check that treatment was successfully manipulated within the research design. In particular, we expected messages from in-group sources to receive more attention. Additionally, we wanted to explore whether the eye tracking data would help to explain effects on other constructs used in the model. We propose this novel use of eye tracking data can be useful in model building, as exemplified in this case by aiding in the interpretation of underlying factors that affect a young adult's behavior towards compliance with a health-related message and/or toward recommending the message to a friend. Hence, in this exploratory study we investigated the correlation between physiological measure of eye movements and the treatments used in our study as well as correlation between eye movements and survey measures that were collected and correlations among the survey measures.

3.1 Research Treatments

As in prior research [20, 21], we developed two separate research treatments which differed only in the message source information. Both treatments presented a self-assessment website hosted by a health screening organization. Treatment A was presented as an in-group message from a member of the campus Health Services staff, and Treatment B was presented as a message from the health screening organization, an "out-group" organization (see Figure 2).

3.2 Participants

Participants were 20 students (9 female and 11 male) at a major university located in the U.S. Northeast. The average age of participants was 20 years. As an incentive to attend the experiment, participants were entered in a drawing to win a $50 gift certificate.

3.3 Measures

We used the survey items by Wilson and Djamasbi [20, 21] to measure the measures personal feedback, message coherence, message involvement and intention to comply with the message. We also designed a new measure, intention to recommend, which captures the participant's intention to recommend the website to a friend. Reliability testing showed that Cronbach's alpha measured .70 or above for all measures, indicating an acceptable level of reliability.

To capture users' reactions to the message we also tracked users' eye movements. To account for individual differences in viewing time (e.g., some people may be faster in reading than others), for each participant we calculated the participant's proportion of total time that was dedicated to viewing the body of the message.

Because our task required participants to view a CMC text message we measured fixation as steady gazes of 60 milliseconds. Studies show that people can read text with fixations as short as 50 to 60 ms [15]. To collect fixation data we used a Tobii X120 eye-tracker.

Email Message From: [redacted]
Subject: Please Try Out Our Self-Assessment Website

Hi everyone,

I wanted to tell you about the Self-Assessment website the Student Development & Counseling Center has linked up with. It provides free, completely confidential guidance in response to anxiety, depression, problems with eating and alcohol use, and other mental health issues. The website is located at http://www.mentalhealthscreening.org/screening/Welcome.aspx, and it can also be found through the SDCC's website (http://www.wpi.edu/Admin/SDCC/about.html).

We recommend the Self-Assessment website highly, and we ask you to check it out. Anxiety, depression, and problems with eating and alcohol use are very common on college campuses, and getting help will make everyone's life better.

The Self-Assessment website can be a great resource for you personally, or for your friends and fellow students.

Best,
[redacted]

(Continues with organization name and contact information)

Treatment A

Email Message From: ScreeningForMentalHealth [redacted]
Subject: Please Try Out Our Self-Assessment Website

Hi everyone,

We wanted to tell you about the Self-Assessment website that Screening For Mental Health has linked up with. It provides free, completely confidential guidance in response to anxiety, depression, problems with eating and alcohol use, and other mental health issues. The website is located at http://www.mentalhealthscreening.org/screening/Welcome.aspx, and it can also be found through Screening for Mental Health's website (http://mentalhealthscreening.org/).

We recommend the Self-Assessment website highly, and we ask you to check it out. Anxiety, depression, and problems with eating and alcohol use are very common on college campuses, and getting help will make everyone's life better.

The Self-Assessment website can be a great resource for you personally, or for your friends and fellow students.

Best,

(Continues with organization name and contact information)

Treatment B

Fig. 2. Research Treatments

4 Results

Contrary to our expectation, the results did not show a significant relationship between the proportion of time spent on viewing the message and whether the message source belonged to the receiver's community or not. Neither did the results show significant correlation between proportion of fixation duration on the message and the perception that one can receive feedback from the sender. The results, however, show significant correlation between the proportion of task time spent on viewing the message and the other survey measures. Because fixations are reliable measure of attention and cognitive processing [14,15], these correlations suggest that higher levels of cognitive processing of the message led to increased scores for message coherence, message involvement, intention to comply with the message, and intention to recommend.

Looking at the survey measures only, the results did not show significant correlation between message source and the rest of the measures. They also did not show significant correlation between personal feedback and other measures.

The results do show strong correlations between message involvement and intention to comply and intention to recommend, however. Additionally they show that intention to comply is significantly correlated with intention to recommend. These are interesting results because they are supported by the eye tracking data. That is, we found physiological evidence for the survey measures that were significantly correlated.

Table 1. Correlation Table for Eye Tracking Data and Survey Measures

Measure	1	2	3	4	5	6
1. Treatment [a]	-					
2. Message fixation ratio	-0.15	-				
3. Message Coherence	-0.07	**0.57***	-			
4. Personal Feedback	0.04	-0.05	0.08	-		
5. Message Involvement	-0.19	**0.47***	**0.59****	0.44	-	
6. Intention to use	-0.06	**0.53***	0.41	0.26	0.76***	-
7. Intention to recommend	-0.36	0.54*	0.34	0.19	0.71***	0.81***

[a] Treatment: 0 = In-group, 1 = Out-group. *p < .05. **p < .01. ***p < .001.

5 Discussion

Our results show that survey measures of message coherence, message involvement, intention to comply, and intention to recommend were significantly correlated with physiological measure of fixation which is an indicator of the amount of attention the message received. Additionally, the results show significant correlations among the survey measures of coherence, involvement, intention to comply, and intention to recommend. Taken together, these results suggest that the above measures are likely to be good candidates for investigating compliance behavior towards health-related messages.

Our results did not show significant correlation between the proportion of fixation duration on message and message source and feedback. These two measures were also not correlated with other survey measures. One possible explanation is that these measures may not be as important in compliance with health-related messages. Another possibility is that a larger sample size is needed to detect such a difference. The latter case, however, indicates that the effect sizes of these measures may be small, hence, supporting the first interpretation.

These results have important theoretical implications because they identify several measures that are likely to be helpful in investigating compliance of young adults towards health-related messages. Additionally, the results introduce the use of eye tracking for identification of relevant constructs in theoretical models. Hence the results show that eye tracking can potentially be useful in instrument development and theory building.

From a practical point of view, results involving message coherence indicate that relevance of messages is likely to have a significant impact on involvement, personal compliance, and recommendation to friends. Thus, messages developed for health-related issues may benefit from a market analysis and persona development which can help to increase the relevance of the message to its intended audience.

As with any experimental study, the generalizeability of the results of this study is limited by its laboratory setting and the task that it used. The controlled laboratory environment allowed us to track users' eyes, a physiological measure that provides a continuous picture of user experience. The task used in our study was designed to be appropriate to the participants of the study, namely young adults attending a university undergraduate program. Future studies are needed to test our results with different tasks and different populations.

As it is typical in eye tracking studies, our study had a small sample size. The relatively low statistical power of this design may have contributed to non-significant results relating to message source and personal feedback, which have been shown to have significant effects in studies with larger samples [20, 21]. Future studies with larger sample sizes are needed to overcome this limitation.

6 Conclusion

The objective of this study was to identify factors that can improve outcomes of health promotion to young adults. We used eye tracking to explore components of an interpersonality model of online persuasion developed for general CMC contexts. The results support the use of eye-tracking in health promotion studies and show that users' eye movement has the potential to serve as a valuable tool in developing experimental treatments and in supporting instrument development and theory building.

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Enabling Access to Healthy Food Alternatives for Low-Income Families: The Role of Mobile Technology

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Abstract. This research explores the barriers that marginalized citizens face with access to healthy alternatives to the high calorie, highly-processed foods available in most urban areas. Numerous barriers, including technology-related ones, are identified and propositions are offered that might reduce the negative effect of these challenges/encounters. From examining the benefit to citizens on public assistance that results from adequate education about healthy eating, to education on the existence of accessible healthy alternatives, and access to inexpensive accessible food sources this study focuses on offering possible real world solutions, both technology-related and non-technology related, to the barriers to inclusion of economically marginalized citizens.

Keywords: Social Entrepreneurship, Farmers' Markets, Government Assistance, Technology Barriers, Innovation.

1 Introduction

Marginalized citizens face many of barriers in accessing healthy alternatives to the high calorie, highly processed foods available in most urban areas. This paper focuses on the barriers that affect those who rely on government Electronic Benefits Transaction cards (EBT) access healthy goods.

A growing number of people working on social issues facing underserved people are social entrepreneurs. Social entrepreneurs adopt the role of change agents in the social sector by adopting a mission to create and sustain social value (Bornstein, 2007; Bornstein and Davis, 2010; Welch, 2008). They recognize and pursue new opportunities to serve that mission by engaging in a process of continuous innovation, adaptation, and learning, acting boldly without being limited by resources currently in hand, and exhibiting greater accountability to the constituencies served and for the outcomes created (Dees, 2001).

Social ventures are needed when "exclusion, marginalization, or suffering of a segment of humanity … lacks the financial means or political clout to achieve any transformative benefit on its own" (Martin and Osberg, 2007, pg. 35). A social

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 245–251, 2013.

entrepreneur can then identify an opportunity and work towards addressing the need through creativity and courage and then direct action.

Although many social entrepreneurs attempt to address one of the Millennium Development Goals (see http://www.undp.org/mdg/index.shtml), a social venture can make meaningful and local impact here in the US. As with ventures working in the developing world, designing a solution targeted at the base of the pyramid is different than targeting the middle or the top (Brown and Wyatt, 2010). One Millennium Development Goal is to halve the proportion of people who suffer from hunger. Although this goal specifically targets developing countries, hunger is something that affects people of all nations, including the US. One of the programs the US government has used to help address this problem is SNAP (Supplemental Nutrition Assistance Program, formerly known as food stamps). The government puts money on an electronic benefit transfer (EBT) card from which families can purchase food from merchants. Unfortunately, the most nutritious and healthy alternatives are often not selected. In fact, the most nutritious and healthy alternatives are often not available at grocery stores, but instead at farmers' markets and road side stands where EBT cards are generally not accepted. In our endeavor to investigate the factors affecting acceptance of EBT cards and the client's use of these markets, we focus our research on farmers' markets.

The first possible barrier is getting the necessary technology to the supplier, which in most cases is the farmer. Secondly, we must overcome the perception by potential clients that boxed and processed food is cheaper than healthy fresh fruits and vegetables. Thirdly, the transportation issues on both ends of the transaction (getting clients to the farm/famers' market or getting the produce to the city) must be addressed. The fourth barrier is addressing the need to engage the farmers in such a way that they recognize the potential client base that exists if they were to allow customers to seamlessly use multiple methods of payment, including EBT cards. Potential strategies to overcome these barriers are discussed in a later section of the paper.

2 Challenges to Connecting Families to Farmers

In the case of connecting low-income people with fresh and healthy food options direct from farmers, several stakeholders are involved. These include the client, the farmer, the government (providing the benefits), and the infrastructure providing the electronic processing of the transaction.

2.1 Family

Anecdotal evidence shows that when farmers' markets don't address the underlying impediments to frequenting them, the success of the venture is not assured. A social venture focused on bringing fresh food from farmers to low-income clients using government-assisted programs includes such things as education on healthy alternatives, mobile commerce solutions for using EBT cards at temporary markets without the need for electricity or hard lined telecommunication, as well as governmental support and inexpensive and convenient transportation.

Education about nutrition and healthy cooking is needed so low-income clients are provided not only with the knowledge to make good purchase decisions, but also with the knowledge to prepare healthy alternatives. The inexpensive processed food that most clients purchase will not lead to healthy living, but only a further decline of the overall health of the US population. Given the skyrocketing costs of health care and the increasing rates of obesity, there should be an incentive to all stakeholders to provide healthy alternatives.

Lack of acceptance of government programs by all merchants, including farmer's markets, hinders the use of these benefits. Many vendors are reluctant to go through the time and money consuming process of getting approval to accept government provided funding through family support programs such as SNAP. As a result families are forced to either pay out of pocket or buy from a source that accepts these types of funding.

Lack of convenient and affordable transportation options is an issue for most of the clients using SNAP benefits. Because farmers' markets are generally located in parks and other locations away from centralized marketplaces, transport to and from the markets is a concern for many families.

The perceived price premium over grocery store options (Goodman, 2011) (and some actual price differential) may lead many families to choose processed food at grocery stores over natural and fresh alternatives. Education not only about the benefits of healthy eating, as outlined above, but also on the actual pricing differential must be offered.

Lack of product variety and weather-related seasonal availability may cause some families to avoid farmers' markets. Because in a grocery store there are readily available fruits and vegetables of the canned and frozen variety offered year round many people choose to consume them over healthier fresh fruits and vegetables that are available at specific times of the year.

The elements outlined above are important aspects of any social venture focusing on this target segment in this manner. To better understand the stakeholders and possible limitations, a family-based model is drawn below (figure 1).

Based on the Family's model we offer five propositions.

We propose that an increase in the number of low-income families using farmers' markets will occur:

1. When proper education programs are offered to potential customers that include basic facts about the assistance programs, the benefits of healthy eating, the ease of preparing fresh, healthy and tasty meals, and the ease of access to a local farmers' market.
2. When widespread acceptance of government assistance benefits (to include EBT cards) are offered by vendors at farmers' markets.
3. When convenient and inexpensive transportation options are provided.
4. When the perceived and actual cost of buying healthy food is comparably priced with pre-packaged and boxed foods found in generic supermarkets.
5. When product variety and seasonal availability can approach that what is seen in local grocery stores.

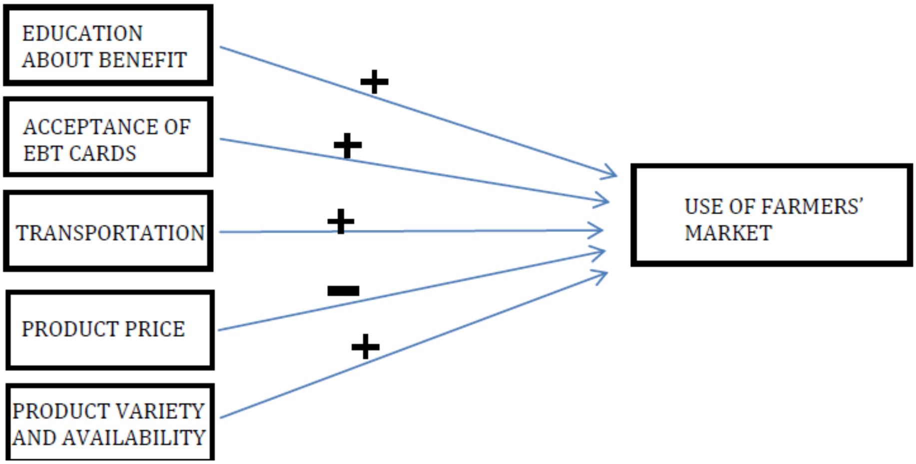

Fig. 1. Family Model

2.2 Farmers

Several metropolitan areas have proactively included the ability to utilize the EBT cards at markets with limited success. Studies (Northpoint, 2009; Kaiser, 2005) have shown that barriers to widespread usage include numerous reality- and perception-based challenges.

Perceived Usefulness (Davis, 1989) refers to how useful a user feels a technology is and is a determinant of adoption. If the farmers feel that using the EBT cards is useful to them (increased revenue, increased traffic at the markets, etc.), they will be more likely to accept them. The more useful the technology is perceived to be, the more likely it will be adopted.

Perceived Ease of Use (Davis, 1989) refers to the amount of effort required to use a technology and is also a determinant of adoption. The lower the effort required the more useful and the more likely a user will adopt the technology. If farmers perceive that little effort is required on their part, they will be more likely to adopt the EBT cards.

Governmental Regulation (perceived and actual "red tape" involved to be authorized to accept EBT cards), if significant and time consuming to process, will affect the farmers' intention of accepting EBT cards (Lieberman, 2011). If the farmers perceive that much effort in terms of sifting through bureaucratic processes is required on their part they will be less likely to adopt the EBT cards. Conversely, if few challenges are present and little effort is required on the famers' part, then the farmers are more likely to adopt the technology.

Cost to use (cost to implement mobile commerce technology and ongoing costs to process payments) is a determinant of adoption from the farmer. As most farmers' markets only accept cash, accepting any cards will incur a fee. This will directly affect the likelihood of adoption by the farmer.

Transportation costs and logistics (proximity to market and potential customers) outside of their normal markets may affect their intention to accept EBT cards. Some farmers actually transport their goods to neighborhoods where customers can purchase goods. Because many lower-income people live in the same neighborhoods, farmers may be more inclined to accept the EBT cards if those neighborhoods are in close proximity to his farm or other markets he frequents.

A model focused on the Farmer is drawn below (Figure 2). The model starts with the basic technology adoption model (TAM), specifically the perceived usefulness and perceived ease of use of the technology solution, and is then expanded to include government regulation, costs to use the cards, and proximity to customers.

Based on the Farmer's model we offer an additional five propositions regarding the influence of factors on intention to accept EBT cards.

We propose that farmers will exhibit higher intention to accept EBT cards:

1. When farmers perceive the usefulness of the mobile device is great enough to allow seamless EBT payments.
2. When the perceived ease of use of the mobile payment method is significant enough to appear worthwhile.
3. When government regulation and "red tape" is reduced to insignificant levels for participating vendors.
4. When the cost to purchase the mobile device and the cost to process transactions is reduced to be effectively a small and insignificant part of the cost of goods sold.
5. When the proximity of the goods to the customer is close enough that spoilage and transportation costs are a small part of the cost of goods sold.

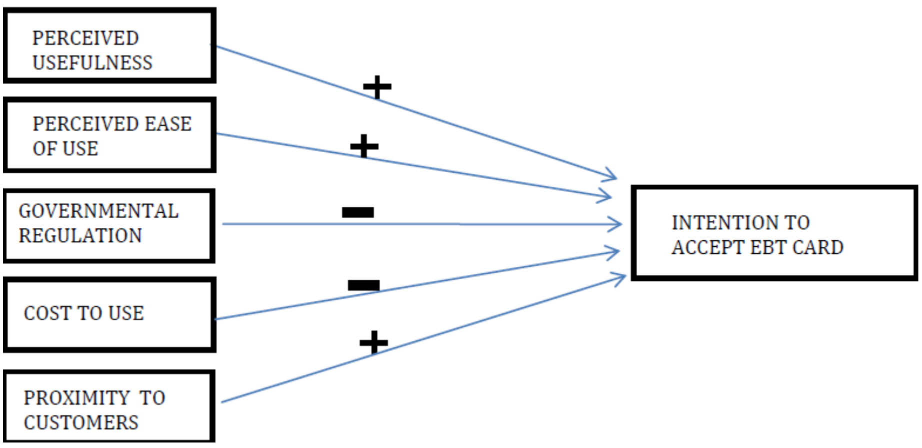

Fig. 2. Farmer Model

3 Research Method, Proposed Analysis and Expected Results

This study will utilize a qualitative data collection method to gather the necessary data from the stakeholders. This data will allow us to take a holistic approach to creating and implementing a mobile-based ecommerce solution allowing low-income EBT users to access fresh, high quality, locally-sourced food. Practical outcomes will include best practices and lessons learned for implementing social ventures focused on healthy food using mobile ecommerce solutions for low-income clients.

4 Conclusions and Current Status

One of the goals of this study is to offer a cost effective means for vendors to offer their products to all market customers through the use of currently available mobile technologies. If the cost can be minimized and methods for product promotion can be included farmers are more apt to take the time to gain government approval to process payments from a customer's EBT card. This will then increase the probability of customers making smart healthy decisions on the foods they feed their families.

This research attempts to develop a more comprehensive model of mobile commerce to be used in a social entrepreneurship endeavor focused on low-income clients using government-assisted programs. The stakeholders have been identified and are currently being interviewed. The results of this study will be presented at HCII 2013.

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Are Prescription Labels Usable? A Review and Analysis

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Abstract. There are approximately 400,000 adverse drug events per year in hospitalized patients which has resulted in more than $ 3.5 billion spent in subsequent recovery care. The present paper reviews the literature relating to the usability of information found on pharmaceutical labels. In particular, we examine the legibility and comprehensibility of the information provided on the labels. In addition, we highlight the differences in the physical makeup of medication that can be implemented to help users identify their medication. Finally, we provide recommendations for factors that should be examined in future research to improve the usability of pharmaceutical labels. Presently, the FDA has few standards and guidelines regarding the content and layout of a prescription label. We hope that the recommendations provided in this paper can lead to the development of standards for formatting and presenting information on prescription labels that will reduce the number of medical cases involving ingestion of the wrong medication.

1 Introduction

As technology encroaches upon traditional fields such as medicine, the need to assess the standards and regulations regarding usage, treatment, handling and management of medical products becomes essential. There are approximately 400,000 adverse drug events per year in hospitalized patients. These incidents have resulted in more than $3.5 billion spent in subsequent recovery care [1]. If these mistakes occur at high frequencies in professional settings such as in hospitals, then they are likely to occur in greater numbers in non-professional settings such as the home. As of today, the FDA has few explicit standards of how a prescription medication label should look and what information the label description should contain. Thus, the goal of this paper was to review the literature on the usability of information provided on prescription labels. We then identify factors that should be examined in future studies to aid the development of guidelines for pharmaceutical labels.

Under Title 21, the Food and Drug Administration (FDA) has listed guidelines for the labeling of substances and filling prescriptions. According to these guidelines, a label should be affixed to the package showing the pharmacy name and address, serial number, date of initial filling, the name of the patient, the name of the practitioner issuing the prescription, the directions for use and cautionary statements (if any, [2]). However, the guidelines do not attest to the effectiveness of the information being

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 252–260, 2013.

placed on the labels or provide specific guidance for how pharmacies should format the information.

The Institute of Safe Medication Practices (ISMP [3]) operates the ISMP Medication Errors Reporting Program (MERP), which is a confidential national voluntary reporting program that provides expert analysis of the systemic causes of medication errors and disseminates recommendations based on these findings. The ISMP provides examples of confusing and unclear labels on its website. To illustrate, a term that has been shown to confuse users is the word "twice." As such, the ISMP suggested that either the word "two" be utilized or the numeral "2" in the place of "twice" to avoid confusion. The FDA has provided some basic guidelines for the structure and content of medication labels. However, as will be shown below, these basic guidelines may not be enough to accommodate the various differences in users' abilities to see, read, comprehend and comply with the information that is contained in the label.

Avorn and Shrank [4] pointed out that the FDA admitted that the current labeling is poorly organized and filled with irrelevant information. Although in 2006, the FDA added some minor changes to the labeling of medication, it was not enough to ensure that patients understand the appearance and dosage of their medication based on the current prescription label. The new labeling regulations called for minor changes that the user may not notice or cannot readily see, such as a section that summarizes the risks and doses at the top of the label, as well as listing all of the risks together. In addition, there is a requirement for the manufacturer to submit an electronic copy of their package insert to the FDA so that it can be placed on the FDA's website. While these changes were made with good intentions, they still do not address the physical layout of the prescription label. As will be shown in the subsequent literature review, there is a need to redesign the current label standards to improve comprehension and identification of the patients' medicine.

2 Comprehension

A major problem with medical labels is that users do not understand all of the information conveyed on the label. For example, Patel, Branch, and Arocha [5] found that people were ingesting the wrong dose of their medication, either over or under dose, due to low literacy. Patel et al. sought to investigate errors in cognitive processes when individuals attempted to read and execute procedures found on pharmaceutical labels of children's medication. The participants were asked to read the labels of each medication and to calculate the dosage of the medication, if it were to be given to their youngest child. They were also asked to think aloud while they read the instructions. There were three different medication labels that were read and interpreted: The first label was from an oral rehydration therapy (ORT), the second label was from an over-the-counter (OTC) cough syrup for children, and the third label was taken from OTC antipyretic drops for children.

Patel et al. [5] found that the majority of the participants performed the task incorrectly. Either they miscalculated the dose or time of day to administer the medication.

While some of the participants were able to calculate the formulas correctly, they restricted or modified administering the medication in the belief that the prescribed amount was too much or too little. For the OTC cough syrup and OTC antipyretic drops conditions, educational level seemed to make no difference in performance. Education level was a major factor for participants in the oral rehydration therapy condition. Only participants with graduate degrees were able to interpret and administer all three stages of the medicine correctly. This finding suggests that there is an underlying literacy factor that needs to be taken into account in the design of medical labels to aid readability and comprehension.

The problem of medical labels being written at a level that is not comprehensible by a large portion of the general population has been documented in countries other than the United States. At the time of their study, Didonet and Mengue [6] found that the Brazilian medication label was written at a level which was higher than the reading level found in public journals and magazines. Using the Flesch Reading Index as a measure of reading level, they found that drug labels were more readable than scientific text but less readable than journalistic texts. In other words, drug labels were found to be difficult to read. Although the Brazilian government tried to address readability concerns two decades ago by passing legislation to improve drug labels, Didonet and Mengue found that drug labels written in accordance with the 1997 legislation did not differ significantly from the drug labels written in accordance with the 2003 legislation. Thus, the 2003 changes in legislation did not improve the readability of the labels. In pursuit of improving drug labels' readability, Didonet and Mengue suggested that medical companies should be obligated to fashion and format drug label text similar to the way in which non-scientific journal texts are written, because the material is intended for the general public.

Although there has been a greater push to get medical companies' compliance, this effort has resulted in the labels containing a lot of jargon aimed toward doctors and pharmacists, and not the end user [7]. In efforts to eliminate a user's reliance on text-dense material that may be riddled with high-level text, pictograms and icons have been studied to determine their effectiveness in relaying information [8, 9, 10]. Using pictorial cues on the labels may help individuals who have low literacy. The visual cues that pictures provide may also aid in identification of the medication inside the container or help point out critical differences between methods of administration (e.g., take the medication orally or have it injected) or side effects (e.g., motor impairments or drowsiness) of the medication. Plimpton and Root [11] concluded that good graphics could help improve comprehension relating to health care in low literacy adults. Thus, adults with low education may benefit significantly from using pictures or pictorial representation on medical labels.

Wolf et al. [12] showed that using pictorial cues could facilitate proper understanding and use of medicine. They compared two newly redesigned labels with a label that follows the current standards for drug warning labels. The two newly designed labels made use of simplified text as well as icons. Both versions used simplified text in which "simple" text was defined as using clearer, more explicit language. Moreover, the text of one version was accompanied by an icon that represented the warning. For example, the warning "shake well" was accompanied by an icon that depicted a hand shaking a bottle. Wolf et al. found that when using the icons, participants frequently noticed the first two warnings on the label. In addition, simplified text labels were attended to more than text on traditional labels regardless of whether they were accompanied by icons. Based on their findings, Wolf et al. concluded that simple explicit language on warning labels can increase patients' understanding of the information on the label. More importantly, including simplified text and icons improved the participants' attention to the information on the label, which allowed for the correct interpretation.

Although pictorial cues such as icons can be helpful, they need to be tested for comprehensibility because some symbols and pictorial representations have to be learned. Ringseis and Caird [13] performed a three-phase study concerning the comprehensibility of pictograms on prescription warning labels. Their main objective was to determine how recognizable and understandable were 20 pharmaceutical warning pictograms. The pictograms were produced by a pharmaceutical company, Pharmex. The participants were shown only the pictogram, with the text that accompanied the warning label removed. Of the 20 labels shown, only four passed the American National Standards (ANSI) requirement for labels, which requires a comprehension level of 85%. In other words, 85% of the participants tested must be able to correctly interpret the pictograms' meaning. Seven of the pictograms passed the International Standards Organization (ISO) requirement where a 67% comprehension level is required. In a follow up study, Ringseis and Caird took 10 warning pictograms that did not meet the standards and redesigned them. For example, a warning pictogram with the intended meaning of "may impair driving" was originally depicted by a car. In the redesign, the new pictogram was a car with a slash through it. Of the 10 redesigned pictograms five of the labels passed the ANSI for the younger population, but only three passed for the older population. This study demonstrates that some pictograms have to be learned, taught, or explained to the user. Thus, the use of pictograms needs to be combined with training in order to be effective.

3 Legibility

Comprehension deals with the user's ability to understand the information that is being presented, such as understanding how often to take the medication. Legibility deals with the perception of the information, that is, whether the user is able to see or read the information being presented. Identification of medicine requires that patients correctly perceive the medicine and the information about the medicine they are taking. This requires that patients identify the medicine's correct name as well as that the pill in the container is the correct medication that was prescribed for them to consume. Therefore, in addition to comprehending how to take their medicine, legibility and/or the ability for participants to see the information on the labels should be taken into take into account. The physical makeup of the label is important because it is usually the only visual representation that the user has of what is inside the bottle. Therefore, the label should be legible and the information on the label should be scannable so that it can be quickly referenced.

One major concern when it comes to legibility is font size. A user cannot read what they cannot see. Bernardini, Ambrogi, Fardella, Perioli, and Grandolini [14] investigated the font size issue in regards to the patient package leaflet in Europe. The leaflet used a size 9 font, and 63% of their participants complained about not being able to read the information because the font size was too small. Wogalter and Vigilante [15] noted that some elderly users have to squint or use a magnifying glass in order to read a prescription label. They found that the use of small font sizes for prescription labels used by elderly adults had the effect of reducing their recall of the information in the label as well as their understanding of that information.

Shrank, Avron, et al. [16] examined font size in regards to the variability and quality of medication labels. They conducted a review of multiple databases in order to gather information that would assist in the facilitation of reading and understanding various prescription labels by consumers. They searched databases such as Medline and the Cochrane Database in order to locate articles that related to the content and format of prescription labels. They found that the use of more white space and simpler language improved legibility, and recommended that these factors be incorporated in the design of medical labels to facilitate comprehension and readability. Additionally, other factors they identified for improving legibility included larger font sizes for the header, lists of ingredients, and names of the medication.

Wallace et al. [17] investigated the readability of prescription inhalers for asthma patients and also found font size to be an important factor. Many labels for these medications were in a font size of 9.2, which made these medications more difficult to read. Thus, Wallace et al. recommended use of larger font sizes. Skelly and Schmuck [18] found that patients in an outpatient facility had less difficulty reading items that were written in a size 14 font. Thus, the use of 14 point font may help with the legibility of prescription labels. Shrank, Agnew-Blais, et al. [7] examined the pharmaceutical labels from six different pharmacies located in four major cities across the country. They noted the size of various attributes (e.g., pharmacy logo, drug name and medication instructions) located on prescriptions labels and found that the largest item was the pharmacy logo, with a mean font size of 13.6. The medication instructions had a mean font size of 9.3 and 8.9 for the drug name. This finding points to the need to prioritize information on the label for the end user.

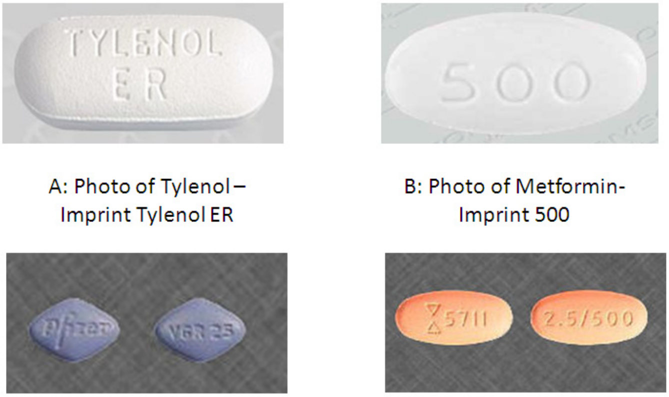
There have also been studies that addressed issues regarding the legibility of text on the current pharmaceutical label. Filik, Purdy, Gale, and Gerrett [19] found that consumers have difficulty with drugs that sound alike and that are spelled alike. They used various methods such as bolding, red color coding, underlining and utilizing brackets in order to improve legibility. They also used a different type of font known as tall man lettering to try to facilitate legibility. Tall man lettering is a technique used to point out a distinction between words that look alike. Upper case lettering is used in conjunction with lower case letters to signify a distinction between two different words that look alike and sound alike [20]. Filik et al. [19] found that tall man lettering was by far a more effective strategy than color coding if the participants are made aware of the purpose of such lettering. Tall man lettering can make similarly spelled drug names less confusing by distinguishing the area of the word that is different. It brings attention to the differences, especially in high risk drug names. The FDA and the Institute of Safe Medication Practice have identified medications that are confusing either due to sound-alike or look-alike qualities. For example, Dopamine and dobutamine are commonly confused words. Tall man lettering would distinguish the two words by highlighting the area of the word that helps distinguish the differences between the words. In this case "amine" is the same in both words, and therefore those letters remain in regular text while the first half of the words is presented in tall man lettering: DOBUTamine DOPamine. If tall man lettering can help users with identifying the medicine's name, then including pictures of what the medication looks like should also reduce ambiguity relating to identifying the correct drug.

In summary, there have been many studies on the legibility and comprehensibility of medical labels, specifically pharmaceutical labels [5] and drug warning labels [12]. These studies showed that medical labels are not written in manner that aids users (patients) in taking their medication. An area that has not been examined, though, is whether the current text description of the medication itself allows users to correctly identify their medication. This issue is important because information on labels can serve as a safety check for drug consumption errors.

4 Properties of Medicine

Generally, when a prescription is filled, the medication is repackaged by hand by the pharmacist and given a new label. The label will contain the patient's name, medication name, and dose of the medication, in addition to a description of the medication and its use [21]. However, problems can arise in this process such as that the medication may be put in the wrong bottle or the pharmacist can place the wrong label on the bottle. Hence, a disparity in the description of the pill and its physical appearance may arise. This problem may not be detrimental for some consumers, especially if the mistake is caught before the pill is ingested. In order for users to accomplish this identification task, though, patients must know what their medication looks like. However, individuals who are taking the medication for the first time usually do not know what the pill should look like and therefore may not question whether they are taking the correct pill. On the other hand, if an individual has taken the medication before, they are likely to be alarmed if the medication looks different than it did in the past, whether the change in the medicine's appearance be a change in color or shape. Based on a literature review, there are four distinct ways that medication varies [22].

1. Shape: compare Figure 1A with Figure 1C
2. Size: compare Figure 1B with Figure 1D
3. Color: compare Figure 1C with Figure 1D
4. Imprints: writing (alpha, numeric, symbol or a combination of any of these)



A: Photo of Tylenol – Imprint Tylenol ER

B: Photo of Metformin- Imprint 500

C: Photo of Viagra– Imprint differs on each side

D: Photo of Glyburide and metformin hydrochloride– Imprint differs on each pill

Fig. 1. Illustration of Medicine and their Properties

Thus, use of pictures of the actual medication on the label may benefit the patients by allowing them to take advantage of a coding mechanism in identifying their medicine. Tylenol (see Figure 1A) is different from Metformin (see Figure 1B). However, they are both white and relatively the same size and only differ by the imprints.

Upon first glance, it is common to dismiss most pills as being the same. To the untrained eye, many pills look very similar. However, after close analysis there are slight deviations in their appearance, such as in their shape or color (see Figures 1C and 1D). The variations are applied intentionally to help medical professionals identify the different types of medicine. Hence, there is reason to pay close attention to the deviations that are present among the pills. Companies, such as the makers of Prevacid, have intentionally used different colors to denote a difference in the dosage. For example, the 15 mg capsule of Prevacid is denoted by a pink and turquoise capsule while the 30 mg capsule is denoted by a pink and black capsule. This distinction is very helpful for the pharmacies to decipher the two dosages. The use of color coding is commonplace in human factors [23] and has been successfully used to aid people with quick and easy identification of items. Here, it is applied to medicine, but the colors used have not been taken advantage of to help patients self-identify their medication to avoid or reduce the medical frequency of errors by highlighting these differences on a label.

5 Recommendations for Future Research

Based on the literature review provided, we recommend examining the following factors in future research to help improve the usability of the information being presented on pharmaceutical labels.

- **Determine a way to simplify instructions.** Patients with low literacy are able to read simple instructions such as "take two tablets by mouth 2 times daily." However, actually demonstrating the daily dosage posed a challenge to patients with low literacy. These findings demonstrate a disconnect in a person's ability to read, comprehend, and carry out simple instructions located on medication labels. Future research should examine how best to simplify instructions for taking medicine that are put on the prescription labels.
- **Identifying the best symbols to use for warnings.** It is clear from the studies reviewed in this paper that many symbols have to be learned. However, certain symbols may be easier to learn and identify than others. Future research should examine what properties of symbols or global symbols are more intuitive than others in order to facilitate the learning and interpretation of the symbols. Additionally, symbols should be researched for comprehensibility before being implemented and used.
- **Determine the effectiveness of using pictures to help users identify their medicine.** While there was an abundance of research on comprehension of pharmaceutical label warning signs, there has not been any research on consumers' recognition of medication. As illustrated in the paper, though, there are many properties of the medicine itself that can be used to help users distinguish between their various medications. Future research should identify the most promising dimensions to use for the coding of the medicine.
- **Determine the best layout of the information.** Where the information about the medicine is printed is important in determining whether users will see and attend to the information. When considering the optimal placement of information, it is necessary to look at how the information will be processed at various locations on the label. For example, English speakers and readers may be able to process information effectively if key information is presented at the top or left locations of the label. This is because this population reads from left to right and top to bottom. However, people from other cultures may not be inclined to read in this spatial pattern. For example, in Hebrew, text is read from right to left first, and in Chinese, text is read top to bottom first. Thus, the optimal location of information may be different for people who speak different languages. How to best place information for different populations of users, then, is another area in need of future research.

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A Dialog Based Speech User Interface of a Makeup Support System for Visually Impaired Persons

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Abstract. A dialog based speech user interface was designed and implemented for a cosmetic facial makeup support system for visually impaired persons. The system helps visually impaired women to makeup her lips, eye blows, and eye shadows using lip sticks, eye blow pencils, and eye shadows. It works as an intelligent dressing mirror using image recognition technologies to judge her performances and to advice corrections. To communicate between the system and users, a dialog based speech user interface is used. Although the system is still a prototype, it was confirmed that the system is usable and useful.

Keywords: dialog based speech interface, visually impaired persons, makeup support system.

1 Introduction

Audible user interfaces such as dialog based speech user interfaces are especially suitable for visually impaired persons because they are hard to use visual user interfaces. Thus, considering systems using audible user interfaces is meaningful to implement reasonable accommodations [1] for visually impaired persons.

We implemented a prototype system of a cosmetic facial makeup support system for visually impaired persons with a dialog based speech user interface.

Facial makeup is good not only to go into social activities but also for mental health. Facial makeup lectures are held for visually impaired women. Most of these classes are on the assumption that sighted helpers support the makeup. However, facial makeup is an intimate thing. It is better for a visually impaired woman to do her own facial makeup by herself without anyone's help.

There are some information technology based makeup support systems such as the makeup simulator [2-5] so far for sighted women. But, as far as we know, there are no systems for visually impaired women, although there are prior researches related to facial makeup of visually impaired persons [6]. Therefore, we studied and implemented a prototype system of a cosmetic facial makeup support system for visually impaired women. This paper explains the implemented system and its user interface and discusses usability and technical issues.

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 261–268, 2013.

2 Description of the Facial Makeup Support System

2.1 System Overview

The system is for facial makeup with cosmetics of ladies. It helps visually impaired women to makeup lips, eye blows, and eye shadows, using lip sticks, eye blow pencils, and eye shadows. It was implemented on a laptop personal computer with internal web camera, speaker, and microphone. The user prepares her cosmetics and sits down in front of the laptop computer. When the application software is launched, it works as an "intelligent" dressing mirror. The web camera captures her face and a close up face is displayed on the screen. Then, the system guides her makeup with a dialog based speech user interface. Applications with dialog based speech user interfaces can be realized in the current development environment of personal computers or smart phones. Using facial image recognition technologies, feedbacks to her trials are returned by voice. Therefore, visually impaired women can makeup her face by herself without helps from others. Fig. 1 shows the overview of the system.

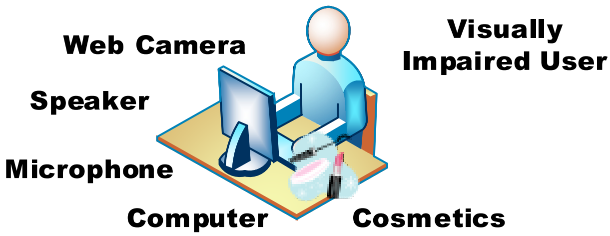


Fig. 1. System Overview. A visually impaired user sits in front of the facial makeup support system consisting of a computer system equipped with speaker, microphone, and web camera. Cosmetics of lip sticks, eye blow pencils and eye shadow are prepared on the desk.

The top level use case diagram of the system in UML is shown in Fig. 2. A user can makeup lips, eye blows, and eye shadows using the system. User can select one of them or do all of them.

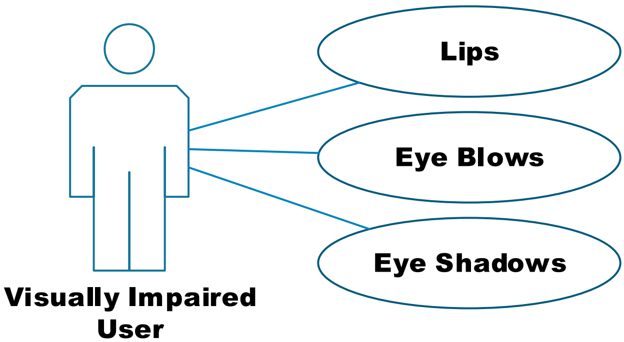


Fig. 2. Use cases of the system

2.2 Dialog Based Speech User Interface

The example dialog is like as shown in Table 1. An example of lip makeup is shown. The original dialogs are in Japanese but they are translated to English in this paper.

At first, the system explains about facial makeup. It includes tutorial introduction of knowledge on the makeup for beginners. Next, it asks user what is the favorite makeup on the day. After the user answered her wish, it instructs how to do the makeup. When she finished her makeup once as instructed, it judges her makeup is well or not. And if needed, it advices suggestion of corrections, until her makeup will be well done.

Table 1. Example Dialog (Original is in Japanese. English translation is shown.)

System	User
Let's start lip makeup. Which color do you want to use, today? Red is women like, pink is younger feeling, orange is active, beige is good for general purpose, brown is adult like, rose is sexy. Please choose one from these 6 colors.	Red, please.
Red, isn't it?	Yes.
Next, which type of red do you want to use? Please choose one from strong, normal, and weak.	Normal, please.
Normal, isn't it?	Yes.
Next, which image of shape do you make? Please choose one from sharp, natural, and soft.	Sharp, please.
Natural, isn't it?	No.
Please repeat.	Sharp, please.
Sharp, isn't it?	Yes.
Let's start. Please paint lips, tops and both corners are like acute-angled triangles. When you finish the paint, please say "Finished".	Finished.
There are 2 wrong parts. At first, the color is sticking out at the upper right center position. Please thin it. When you finish, please say "Finished".	Finished.
Well done. Next, the top center is thin. Please make it bold. When you finish, please say "Finished".	Finished.
All done. There is no parts to be modified. Good job.	Thank you.

2.3 Graphical User Interface

Even if the system is for visually impaired persons, a simple graphical user interface is supplied, although the main user interface is the dialog based speech. A simple graphical user interface which have large texts on large buttons can be used by low vision users. Also, screen readers usually used by blind persons work on textual labels of the graphical user interface.

The interface works as a magnifying mirror for the facial makeup. A web camera captured image is displayed on the screen in real time (Fig. 3). In addition, some large

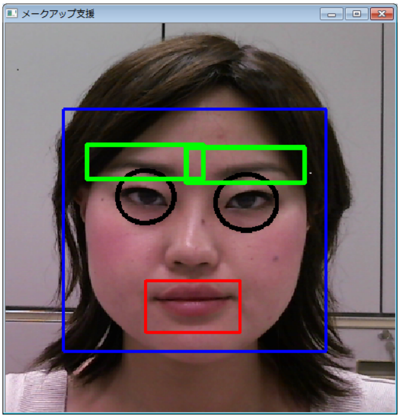


Fig. 3. Facial areas detection from a web camera captured image

text buttons are displayed on a window for simple commands like, start, stop, lips/eye blow/eye shadow selection, volume controls, etc.

2.4 Beginner and Advanced Modes

The system supports, so far, beginner and advanced modes. The previous example dialog in Table 1 is in beginner mode. In the advanced mode for daily users, the explanation words are less. In dialog in real situations, already known information is not said. If already know facts or redundant sentences are said, people are depressed and irritated. Or, unknown information is not supplied, it is inattentive and users cannot complete their purpose. Thus, dialog should be designed carefully. In the next stage, we plan to make more varieties and configurations depending on users' characteristics, expertise, and situations.

3 Prototype Implementation

3.1 Development Environment

The current version of the system has been implemented using Microsoft Visual C++ Express Edition. Programming language used is Visual C++. For camera image input and image processing algorithms, OpenCV [7] (currently, version 2.4.2) is used. For speech user interface, Media class and SAPI (Speech Application Programming Interface) in .NET Framework are used. Running environment is Microsoft Windows 7. A laptop computer with internal speaker and built-in microphone and web camera is used for the system.

3.2 Facial Image Recognition Program

An important function of the system is facial image recognition to judge user's performances.

For capturing images from a web camera, OpenCV library [7] is used. For the region extraction of the facial parts, Haar-like characteristics [8] is used. Using a sample program and algorithms proposed by prior researches [9] [10], a program for the extraction of facial, eye blow, and eye areas as shown in Fig. 4 was implemented.

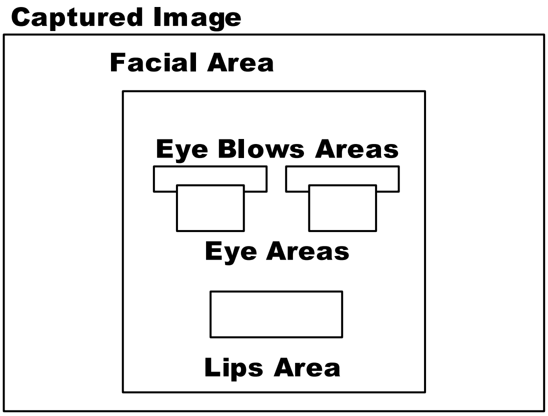
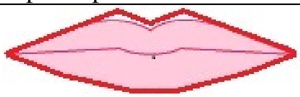
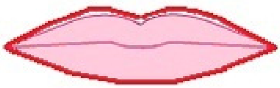
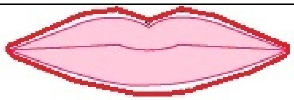


Fig. 4. Facial area detecting by image recognition algorithms

3.3 Lips Makeup System

Types of lip shapes by impressions supported in this system is shown in Table 2. Sharp, natural, and soft are used depending on impressions of shapes. When a user say "Finished," the system judge the shape according the criteria of Table 2. If the system finds sticking out, unpainted, or wrong shapes parts, it advices for the user where and how to correct her drawing. For expressing a specific point on lips, 16 positions shown in Fig. 5 are named such as upper center, upper-right-1, upper-right-2, and so on.

Table 2. Impression by types of lip shape drawings

Impression	Lips shape	Drawing instruction
Sharp		Color in straight lines with acute angles at the end and tops.
Natural		Color along with lip shapes.
Soft		Color with rounded shapes.

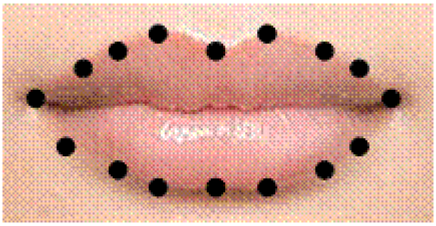


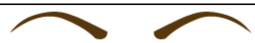
Fig. 5. Lip points for advising corrections

3.4 Eye Blow Makeup System

Table 3 shows the supported shapes of eye blows. Well matched eye blow color is closely related to hair color, the system recommends an eye blow color well matched to the user's hair color, although the user's own choice can be done.

Since eye blow makeup is difficult for beginners even by sighted women, eye blow templates are used to draw eye blows with an eye blow pencil. Suggested template is recommended by the system after asking the user for her favorite impression of the day.

Table 3. Impressions and shapes of eye blows

Impression	Eye blow shape
Natural	
Soft	
Gallant	
Fresh	
Sharp	

3.5 Eye Shadow Makeup System

Eye shadow is painted with gradually changing color in depth. Eye blow ends vertically and corners of eyes horizontally directions should be in deeper color. By detecting color and brightness of the eye shadow area, the system suggests corrections (Fig. 6).

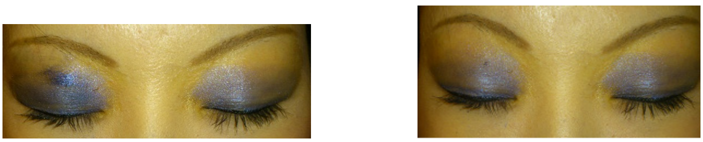


Fig. 6. Correction instructed by the eye shadow makeup system (Before and After)

3.6 Speech User Interface

The speech user interface was implemented. The currently supported language is Japanese only. .NET Framework supports speech synthesis and recognition application programming interfaces (API) as standard functions, although a synthesis engine must be installed. The speech recognition used here is for limited words not for dictation of any of natural sentences. This limited word type recognition is usually used for voice commands. Dictation of sentences are not always succeeded to be recognized but limited words recognition is easier and feasible. For example, at the selection of color, only supported color names can be recognized.

The synthesis engine used in the current system is Document Talker [11] popularly used in Japan for Japanese speech synthesizer. The speech synthesis is less fluently than human but it has enough readability.

4 Evaluation and Discussion

Although the parts of the image recognition and the judgment to the makeup have not reached to the reasonable quality yet, with the current system, it was tested whether makeup can be done or not, mainly focusing to the evaluation of the dialog parts. Subjects are women with sight and they close their eyes during the experiment. As a result, subjects can do makeup by the dialog system. After the experiment, hearing was done from the subjects. The advanced mode was felt better for repeated use of the system. After routines of testing and improvements, interviews were done from professional members of the staff at a public information and culture center for visually impaired persons. They checked the system and stated their thought and suggestions. As a result, it can be said that the system is useful and good for visually impaired women.

5 Summary

In summary, dialog based speech user interface is promising to visually impaired persons support systems. However, the practical know-how to implementations for visually impaired persons has not been accumulated enough, yet. Our work is still undergoing but presenting the details of our prototype system of a makeup support system for visually impaired persons is helpful to researchers and developers of human computer interaction.

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The Urgent Communication System for Deaf and Language Dysfunction People

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Abstract. This paper discusses the usefulness of the Urgent Communication System (UCS) on mobile device that is originally proposed by a hearing impaired person. Since the UCS is simple menu like pictogram sheet and the patient is simply to point the pain portion or severe level by the finger to communicate with remote supporters. Then the UCS is to particularly focus on the communication method of complaint of pain/ache/grief by hearing impaired patients. The UCS is drawn by icons and pictograms with help of minimum selected key words. Ache portions are drawn in the two dimensions. UCS is implemented on mobile touch panels applying nine functions above such as iPad and Android devices to make hearing impaired or language dysfunction people communicate the remote supports in such urgent situations through the IT clouds. Proposed UCS is evaluated by hearing impaired people in the manner of the usability test. The results by the hearing impaired people with UCS are that the time to collaborate is shorter for about 70%. In the interview after the evaluation, many hearing impaired people pointed out that this service will ease their predicted mental concern at the emergency.

Keywords: Human Centred Design, Usability, Accessibility, CSCW, Touch Panel.

1 Introduction

This paper discusses the usefulness of the Urgent Communication System (UCS) on mobile device that is originally proposed by a hearing impaired person. Their appearances are the same in the daily life. However at the unexpected situation, they will be suddenly in trouble at such the occasion of disasters or accidents. For instance at the time of Great East Japan Earthquake of March 2011, hearing impaired people must face serious problems particularly on communication issues. In such an extreme situation, the surrounding people could not afford to help or support such hearing impaired people since they were limited to take care themselves and their family.

Since the UCS is simple menu like pictogram sheet and the patient is simply to point the pain portion or severe level by the finger to communicate with remote

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 269–274, 2013.

supporters. They are drawn by the collections of the pictograms on the mobile device display with a touch panel [1]. This contributes the effectiveness and efficiency of the communication and collaboration between them since the selections of the pictogram are representing disabled people requirements and lifesavers. The UCS on mobile device with touch panel can be then used not only by the hearing impaired people but also by universal users such as foreigners or language dysfunction people.

2 Pre-survey and Determining the Context

Hearing impaired people are asked their difficulties of the sudden situation at the time of the very first of the survey following to Human Centred Design (HCD) [2]. Data by emergency patient complaint from Tokyo Fire Department, Medical Department in Keio University and Kasuga Onojo Nakagawa Fire Department in Kyushu prefecture are collected and analyzed by clustering. Selected ten patient complaint items of the data are; pain/ache/grief, unconsciousness, hard of breathing, fever, faint, convulsion, vomiting, hard of standing up and walking, cardiopulmonary problem, and external injury.

3 Concept and System Design

From the point of "Context of Use" [3], the UCS will not be necessary to cover all situations. In conclusion it is best useful, effective and particularly efficient at the hearing impaired and language dysfunction people complaint of pain/ache/grief among the selected ten patient complaint items. Then the UCS is to particularly focus on the communication method [4] of complaint of pain/ache/grief by hearing impaired patients [5].

The ache portions are to be positioned head, face, chest, back, belly, waist, hands and leg/foot. Hence three ache depths come from surface skin, visceral and bone. The hearing impaired and language dysfunction people complaint of pain/ache/grief and external injury is to be drawn by pictograms and icons that are easy to understand even such emergency situation for them.

The UCS is drawn by icons and pictograms [6, 7] with help of minimum selected key words [8] with Multivariate Analysis (MVA) [9, 10]. Ache portions are drawn in two dimensions. Ache depth and severe pain are in the third dimension. The hearing impaired and people will simply touch the designated icon or pictogram to communicate the remote support people in such emergency situation by ubiquitously carrying the mobile device with touch panel. The mobile device is equipped the following nine functions; Tap to select, Double tap to do scaling, Drag to jump, Flick to move next page, Pinch in/out with double fingers, accelerate sensor to position upright, Photo browsing to display icons or pictograms, Backlight for dark place usage, and Wi-Fi function to download the new contents.

The UCS is implemented on mobile touch panels applying nine functions above such as iPad and Android devices to make hearing impaired or language dysfunction people communicate the remote supports in such urgent situations through the IT clouds. The mobile device with touch panel will produce document sentences of e-mail through simply pushing on icons or pictograms by the hearing impaired people. Then the mail sentence is to be instantly sent to the remote supporters.

Currently 31 screen contents on UCS are implemented by the software development kit (SDK) of MIT APP Innovator [11] and distributed onto Android touch panel terminal by DeployGete [12] for the evaluation (Figure 1). The users are simply tapping the icons or pictograms on the sequences on the screen. The screen transition process is based on the telephone dialogues of the command console of the Kasuga.Onojo.Nakagawa Fire Department in Kyushu Prefecture. Then the process is analyzed and drawn by Freeplane [13] of mind mapping (Figure 2). The UCS includes the cognitive design method on Automated teller machine (ATM) for elderly people since under such a urgent situation people would be upset and hard to communicate just like a cognitive decline [14, 15]. They are as following three points;

- Simple selection way with limited choices
- Explicit sliding at the time of screen change
- Confirmation after the selection

Fig. 1. UCS on Mobile Device with Touch Panel

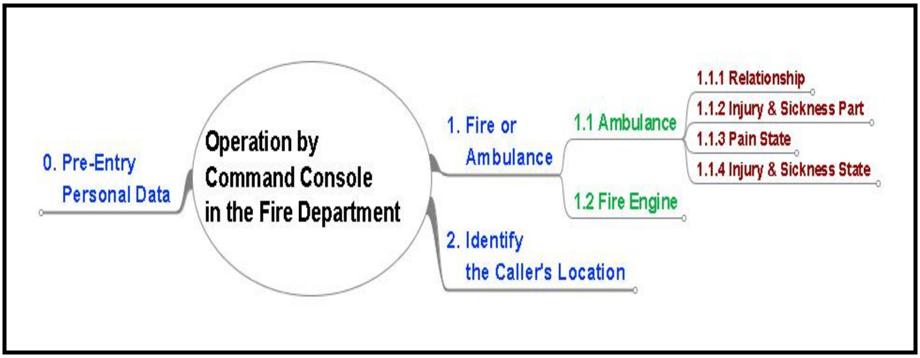

Fig. 2. Process Analysis by the Command Console in the Fire Department

4 Evaluation

Proposed UCS is evaluated by hearing impaired people in the manner of the usability test. The four tasks are prepared to compare with and without the service. They are to call ambulance and fire brigades. The evaluation test was performed by four hearing impaired participants (subjects) with following five steps (Figure 3). All experiment instructions are introduced to hearing impaired subjects by a sign interpreter. A memo note is permitted to use.

- Task-1: Fire report with UCS.
  This scenario is that "The forest is on fire. I recognize a flame but no fume. I am safe since I am away from the fire spot. There is no injury. Please help".
- Task-2: Fire report by e-mail
  The scenario is "This building is on fire. My floor is different from the fire spot. I cannot recognize flame but fume. There are some injuries. Please help".
- Task-3: Ambulance request by e-mail
  The scenario is "Please call ambulance since I was run over by a car. I am middle aged male. I am conscious but my leg is broken with blooding. It is quite painful. I have once experienced fracture and took to surgery. Please deliver an ambulance soon".
- Task-4: Ambulance request by UCS
  The scenario is "My daughter is urgent sick. She is grown up and pregnant. She might be preterm birth. She is conscious but appeals her savior pain in the belly. She was once suffering from gallstones. Please deliver an ambulance soon".
- Task-5: Filling out the pre-entry personal data
  A trial to fill out the personal data sheet such as name, address, age and one's disease history with using either with a soft key board or with hand writing input.

Fig. 3. The Evaluation Experiment with UCS

The results must be analyzed under "the Context of Use" [3] whose result is measured by the Effectiveness, Efficiency and Satisfaction. This evaluation opportunity focused particularly on the Efficiency with comparing two options between applying UCS and without it.

Table 1. The Results on Efficiency Applying UCS

Subjects	Task-1	Task-2	Task-3	Task-4
MKS	12"82	3'40"07	2'45"28	53"26
YNY	24"20	1'34"08	2'23"72	59"85
SZKM	19"52	1'54"84	2'02"72	49"72
SZKK	20"87	1'06"68	2'01"68	N/A
Average	19"35	2'03"92	2'18"35	54"28

5 Conclusion and Discussions

The results on Efficiency by the hearing impaired people with UCS are that the time to collaborate is shorter for about 70% in Table 1. In the interview after the evaluation, many hearing impaired people pointed out that this service will ease their predicted mental concern at the emergency. This concept is close relationship to the Satisfaction in the Context of Use or User Experience (UX) [16].

The original booklet of UCS was translated into English, Spanish, Korean, Chinese and Portuguese for the foreign people staying in Japan. The results by the foreign people with UCS are that the time to collaborate is shorter 20% and the messages of the dialogue are more precise 20%. In practice it is currently carried by several ambulances in the local fire departments to aid to collaborate between the hearing impaired patient and lifesavers. The outcome of this research will be also proposed to Japanese government to have the available to prepare such a crisis to communicate urgently and remotely very near future.

The current study is to implement the booklet UCS onto the mobile device with touch panel. The following study is to connect this system up to the ICT cloud. The end users of inclusive ubiquitous use are to down load this service from the home page of Architectural Association of Japanese DEAF as well as designated fire stations posted in the cloud. They are allowed to carry, use, copy, and modify the pattern for their personal use.

Acknowledgement. This research is supported and funded by the Project organized by Fire and Disaster Management Agency under Ministry of Internal Affairs and Communications (MIC) of Japan. A collection of local sign language database is supplied and permitted for research use by Mr. M. Akatsuka of Architectural Association of Japanese DEAF (AAJD). Dr. H. Akatsu of Oki Electric Ind. Co., Ltd. introduced the cognitive design method on ATM for elderly people.

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Qualitative Study for Designing Peripheral Communication between Hospitalized Children and Their Family Members

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Abstract. This paper describes an effort to develop a new communication supporting environment which engenders a greater sense of social proximity among geographically distributed families, particularly between hospitalized children and their families. We conducted a qualitative study including two in-depth field interviews with in-hospital school teachers and the mother of a hospitalized child. The results from qualitative analysis provided us with insight into the organization of the interactions between the hospitalized child and the family. On the basis of the results, we established a set of design principles and developed four different types of technology prototypes for peripheral communication. The design principles played a splicing role in binding the heterogeneous processes of qualitative research and the development of prototypes. Future works involve the enhancement of design principles and prototypes, and methodological improvements.

Keywords: qualitative research, hospitalized children, peripheral communication, distributed family.

1 Introduction

This paper describes an effort to develop a new communication supporting environment which engenders a greater sense of social proximity among geographically distributed family members, particularly between hospitalized children and their families.

The support system of hospitalized children consists of various resources including a hospital, family, local and in-hospital schools [1-2], and counselors and volunteers, which play significant roles in terms of various aspects of the system (Fig. 1). Children with serious medical conditions may expect certain responses from people and/or services: help with feeling better and managing their lives better, empathic understanding of their situation and no fussing [1]. Parental participation is viewed as a pivotal concept to the provision of high-quality nursing care for children [3]. In particular, interactions between parents and children play a critical role in long-term nursing of a hospitalized child. However, most studies of children with chronic or serious conditions are medically, psychologically, or sociologically orientated [1]; few focus on the perspective of support for family.

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 275–284, 2013.

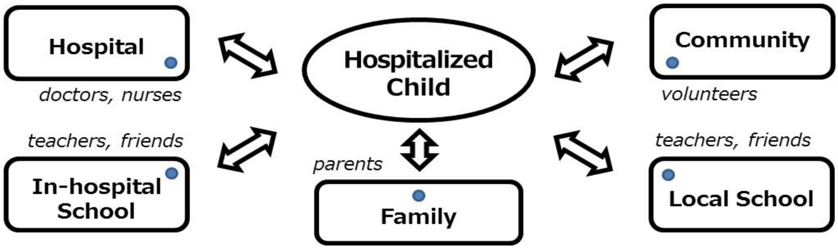

Fig. 1. Support system of hospitalized children

1.1 Peripheral Communications among Family

Family members who live together consciously or unconsciously convey, perceive, and share various types of peripheral information in their everyday lives [4], *e.g.*, cues of tone of voice, singing in the kitchen, the pace of footsteps, doors being slammed shut, light or music leaking through a door, and the aroma of coffee brewing. Each family has an individual style of using these cues to gain awareness of the mood or physical presence of its members. When family members move apart, these cues are no longer shared, which diminishes the sense of close contact the family previously enjoyed. In particular, hospitalized children and their families are provided with very limited opportunities for daily family interactions, resulting in a serious consequences for family members of hospitalized children, particularly for mothers, who sometimes experience serious "separation anxiety."

1.2 Related Works and Our Approach: Supporting Families Who Live-Apart

Home technologies that aim to assist family members while living apart can be found in human-computer interaction (HCI) area. Efforts include the use of various digital props, for example, internet teapot, family portraits [5], digital décor [6], an augmented planter [7], a jacket for "hug over a distance" [8], and an interactive installation supporting touch over a distance [9] that senses and conveys physical motion and the touch of remote family members. Despite the apparent simplicity of these devices, family members reported emotional affects resulting from their placement in the home.

In this paper, we examine peripheral communication between hospitalized children and their families. We consider an integrated approach that combines qualitative study and the development of a new communication supporting environment. Our process consisted of a field interview, qualitative analysis, establishment of design principles, and development of peripheral communication prototypes.

2 Qualitative Research

To begin with, we conducted two field studies. The *triangulation* of methods and data [10-11] was taken into account. To investigate multiple aspects of the interactions between hospitalized children and their families on different levels, we adopted a combination of multiple qualitative research methods [12-13] such as semi-structured interviews, participant observation, and questionnaires. The first study addressed in-hospital school teachers, while the second study addressed the mother of a child with repeated long-term hospitalization.

2.1 In-Depth Interview 1 (Teachers at an In-Hospital School)

In the first study, we focused on in-hospital school teachers, given their familiarity with a hospitalized child's everyday life and the likelihood that their perspective is different from that of the child's family. The study aimed to determine important clues for interpreting and sensing moods and other various conditions of hospitalized children's everyday lives, including in-hospital school lives, intentionally with the exception of their medical conditions.

Participants. We met two experienced teachers, "A" and "B" (female, in their late 40s and early 50s when interviewed), of an in-hospital school affiliated with the university hospital located in a suburb outside of Tokyo. Both had five years of experience teaching at the in-hospital school in addition to elementary schools.

Method and Research Settings. The research session involved semi-structured interviews [14], a set of questionnaires, in-situ contextual inquiry, and open-ended discussion. The interviews included several topics such as (a) in-hospital school life and its place in the lives of hospitalized children, (b) aspects of everyday life conditions that children avoid displaying to their families, (c) considerations while communicating with children, and (d) clues for recognizing children's emotional state. In addition, we also conducted participant observation [15] during in-hospital classes (a "housecraft" class at the elementary school and an "art" class at the secondary school) to further understand children's everyday lives in a hospital. The session was conducted at an in-hospital school in December, 2009 and lasted for approximately two and a half hours.

2.2 In-Depth Interview 2 (Life Story of a Mother of a Hospitalized Child)

In the second study, we focused on a mother of a child hospitalized on a long-term basis. The second study aimed to understand the life history of a child and the family, including memorable family episodes, and the style of interaction between them, and determine important peripheral communication cues for interpreting and sensing presence, mood, and various conditions of children's everyday life in a hospital and at home, with the exception of their medical conditions.

Participants. The participant "M" was a mother (female, aged 44 when interviewed, full-time housewife) of two children. She lived in a suburb outside of Tokyo with her husband of 17 years and their children. Their first child, "H" (female, aged 14), had a cardiac disease since birth and had had several long-term hospitalizations. On the other hand, her husband canceled his participation.

Method and Research Settings. Research was divided into three sessions. During the initial session, we emphasized the establishment of a *rapport* with the participant and her partner, the informed consent process, and building a relationship of mutual trust. The second and third sessions involved semi-structured interviews, life story interviews [16-17], a set of questionnaires, and open-ended discussion. The interviews included several topics such as (a) family structure and current situation; (b) a biographical sketch, including memorable events; (c) life story, including her personal experiences of continuously nursing her first child, who suffered from a cardiac disease; and (d) important peripheral communication cues for interpreting and sensing mood, presence, and various conditions of children's everyday lives (with exception of their medical conditions) in a hospital and at home. The sessions were conducted between August and December, 2009 in the living room of her house on an individual basis and lasted for approximately four and a half hours in total.

2.3 Results

All interviews were transcribed into readable narrative texts. First, the transcripts were subdivided into key experiential units (i.e., segments) and encoded with a set of characteristics selected from the established analysis viewpoints. Furthermore, the narrative interviews were interpreted according to the sequence of analysis stages ([13], p.346): (1) analysis of biographical data of the family, (2) sequential analysis of the text and thematic field analysis, (3) reconstruction of the life story (life as told), (4) reconstruction of the case life history (life as lived), (5) detailed analysis of individual textual segments, and (6) contrastive comparison of life history and life story. Table 1 shows an example.

The analysis results obtained from qualitative research provided us with deep insights into the organization of the interactions between the hospitalized child and the family. They indicated that (a) a mother plays a very unique and critical role in the family in terms of long-term nursing, particularly with regard to interactions with a hospitalized child, though she seriously feels isolated at times; (b) the interaction style and relationships among a hospitalized child, the mother, and family had changed during key family events; and (c) rather than vital signs of medical conditions, simple ordinary peripheral cues exchanged among family members, particularly between a mother and her hospitalized child, were important for knowing everyday life events and maintaining their feeling of closely connected. We identified important peripheral cues that a mother used for interpreting moods and various conditions of a hospitalized child and various aspects of a mother's concerns about the everyday life of her child in a hospital and at home.

Table 1. Events in "M's" life history and excerpts from narrative data relevant to the events

	Events in "M's" life history	Excerpts from narratives on personal experiences relevant to the events
"H's" birth	• The first child "H" was born. • "H" was diagnosed with a serious heart condition at birth and her arterial oxygen saturation was 30. • "H" was immediately moved to a university hospital with "M's" husband and grandfather. The doctor informed "M's" husband that the newborn baby might die. • "H" (univ. hospital), "M" (maternity hospital), and her husband (home) suddenly separated.	— "I noticed a newborn nursery where 'H' had to lie was silent in the darkness." — "Papa didn't tell me what happened with our baby; probably he prevented me from being hurt. But I guessed it because I smelled like disinfectants as my husband came back to me. Usually, I never smelled such things in a maternity hospital." — "No, no, no… my greatest crisis, that should be the worst time of my life. I was dropped into the depth of unbearable sorrow, at bottom of the hell."
"H's" first operation	• On the second day, "M" went to the university hospital for "H's" emergency operation (50% success rate). The doctor said that "H" could die if the blood would spout from the heart. A hospital official advised the parents to call a relative. • When "H" returned to the Pediatric ICU, "M" saw "H's" entire body covered in tubes. • Thereafter, "M" visited "H" daily for three months. That was the beginning of "M's" long-term nursing of "H."	— "The doctor (of the university hospital) showed us a great readiness to care 'H'. When he gave me strong encouragement, I answered YES in a strong tone. I thought 'H' would survive when I saw a smile of nurse." — "Nurse said me they would be able to care 'H' but please take care of me by myself. At first I couldn't perceive what nurse meant but now I well understand." — "Actually, I almost did nothing while visiting, but I felt myself pulled by the hair from behind as I left there." — "Yes, I believe, it's me who protect 'H'. I do anything for 'H'."
Domiciliary treatment	• After leaving the hospital, the parents continued domiciliary treatment for "H" by using a machine for supplying oxygen on a 24-hour basis. "M" or her husband needed to exchange and insert a tube into "H's" body after every bath.	— "It is business for a baby to cry. But, crying puts a heavy burden on the 'H's' heart. I tried not to let 'H' cry as much as possible. Extremely hard." — "'H' couldn't sleep well when quiet. Perhaps, because she was always surrounded by noises from medical machines."
"H's" third operation at two years old	• "H" had a third cardiac surgery. • "M" asked the hospital for support for mother-child *separation anxiety*. "M" was allowed to stay in "H's" room in the hospital all day for three weeks. "H" bitterly cried as she woke to find herself left alone. The bed was replete with small stuffed toys. • In those days, "M's" husband was very busy with his work. After work, he would sometimes stop by at the hospital and have supper with "M." • "M" couldn't tell her parents about her everyday life with "H."	— "Prior to the surgery, nurse prompted me to wipe and clean 'H's' body, but I didn't understand it … a possible serious situation. — "So, I had to go shopping for groceries quickly while 'H' was asleep. I worried during my separation whether 'H' was crying, and always wanted to know how things were going with 'H'." — "Like a stuffed doll, I'd been with 'H' all day long and slept with her in the same bed." — "I went almost crazy. But, am mom. Became strong afterwards. However, I heard some mothers who went crazy in such a situation." — "I expected if papa could have heard my story a little more. Honestly, he didn't support me very much. — I didn't want to have an advice from parents, but expected them to hear me."

3 Designing Prototypes

Om the basis of the results of the qualitative study, we established a set of design principles for guiding the development of our new communication supporting environment. The insight into the organization of the interactions between hospitalized children and their families deeply influenced the formulation of the design principles.

3.1 Establishing Design Principles

The following principles were established for designing prototypes which aimed to engender a greater sense of social proximity among geographically distributed family members and improve their emotional well-being.

- Take advantage of familiarity with everyday things [18] and design it with "*periphery*" [19]
- Help the families to remind various scenes of the children's everyday lives, and help them to engender the feeling of being closely connected
- Emphasize peripheral cues and specific sensory experiences that the children and parents enjoy during their everyday-life experiences [20]
- Focus on the clues for feeling the workings of the children's lives but avoid directly transmitting vital signs and taking the role as an emergency call.

3.2 Four Types of Prototypes

We designed four different types of prototypes based on the design principles.

Prototype A ("Awake-or-Asleep"). "Awake-or-Asleep" is an accessory for cellphones, which displays a picture expressing the activity of a hospitalized child and conveys the information to the family at home (Fig.2 - left). It (a) senses the movements of a hospitalized child by using pressure sensors embedded in a child's bed, and based on the analysis of movements, (b) displays a picture representing the status of whether a child is awake, asleep, or actively moving.

Prototype B ("Did-it-Today"). "Did-it-Today" is a variation of "Peek-a-Drawer" [6], an impressive digital décor by Siio. Its concept and user scenarios inspired us to design "Did-it-Today," which helps hospitalized children to tell their families about what they did at a hospital that day. When (a) a hospitalized child puts something (*e.g.*, a notebook page or a handcraft a child created that day) into a drawer and closes it, (b) a photograph of the thing is automatically taken, and then (c) the image is transmitted via internet and appears on a small display in the home. We used a paper-mockup version.

Prototype C ("Breathing Toy"). The "Breathing Toy" (Fig.2 - center) is a stuffed doll designed to imitate the movements of human respiration. It (a) captures the motions of respiration of a mother at home by using PVDF-based sensor, (b) translates it into the sequence of control signals of a precise steeper motor, and digitally controls reciprocal motions of syringes using a linear actuator with a stepper motor, and then (c) reproduces the movements of respiration by pumping a small rubber balloon embedded in a toy and simulates mother's breathing at bedside in a hospital where her child is and vice versa (i.e., from a hospitalized child to the mother at home).

Prototype D ("Touching-a-Breath"). The "Touching-a-Breath" (Fig.2 - right) is a cushion designed to imitate chest movements of human respiration. Similar to the "Breathing Toy," it (a) captures the motions of respiration, (b) translates it into the control signals for controlling reciprocal motions of syringes using a stepper motor, and (c) reproduces chest movements of respiration by pumping a rubber bladder embedded in a cushion, thus simulating the mother's chest movements at bedside in a hospital, and vice versa (i.e., from a hospitalized child to the mother at home).

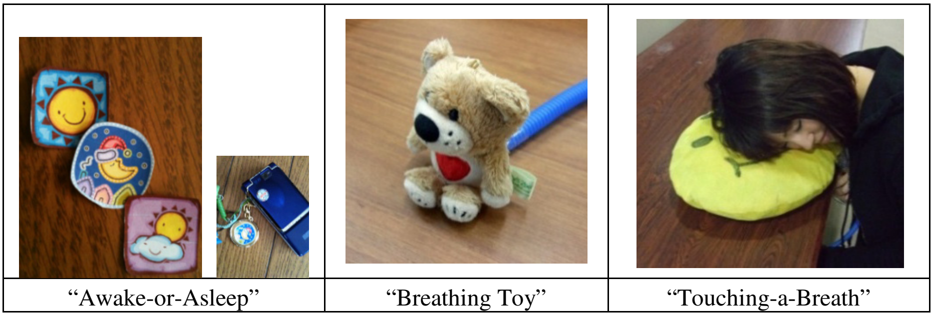

Fig. 2. Prototypes of peripheral communication between hospitalized children and their families

3.3 Field Evaluation

The initial field evaluation was performed in March 2010 using four different types of prototypes (from A to D) described in the previous section. One respondent from our previous field study (participant "M," female, aged 44) participated. Her first child "H" (female, aged 14) was diagnosed with cardiac disease at birth and experienced repeated long-term hospitalizations.

The session was conducted individually in the living room of her house in a suburb outside of Tokyo, Japan. In this field session, we used mockup versions of the "Awake-or-Asleep" and "Did-it-Today," and workable prototypes of the "Breathing Toy" and "Touching-a-Breath." The "Breathing Toy" and "Touching-a-Breath" were installed in their living spaces. Because of network limitation, we used a stand-alone version. Following an introductory component, including informed consent, we demonstrated each prototype along a user scenario, and then, the participant was asked to evaluate each prototype after using it for some time. The interview involved an interactive semi-structured interview, completion of a questionnaire (ratings), and an open-ended discussion. In addition, the participants were asked to think aloud about their feelings and thoughts while trying and evaluating. The interview contained several topics, for example, the potential for (a) softening feelings of tension, anxiety, and loneliness of a mother; (b) stimulating feeling of being with the child and feeling love for the child and life of the child; (c) feeling pleasant or being bored following long-term usage; (d) matching the actual situation. The session lasted for approximately two and a half hours in total.

Results and Discussions. An excerpt from the participant's verbal responses to each prototype obtained during the evaluation session is included in Table 2.

Table 2. Comments on the prototypes obtained from the evaluation session

Proto type	Verbal data obtained while trying and evaluating prototypes
A	"I was anxious while I had to go for shopping or laundry, about if 'H' cried." "If I know 'H's' situation in the in-hospital school or her mental condition beforehand, we can talk more smoothly when meeting a child." "In the case (of emergency), a cell-phone will be most helpful."
B	"I am glad that I can see she struggles in the things other than the disease." "This seems to be more helpful in a case of children with cancers. They usually have a long hospitalization. Or in a case that a hospital is far from their houses.
C	"I always minded how 'H' was awake, eating or sleeping in the hospital. If the toy changed its movement, I would probably wish to know the reason why." "For me, the person is better than a thing. I'll go there to see her, actually!"
D	(After burying her face in the cushion and tasting its movements slowly for a while) "It's nice… it seems I'm with my child… Oh, 'H' (she called for the name of H)." "If I hear from a nurse that 'H' sleeps well using it, I don't mind wearing a belt of a sensor."

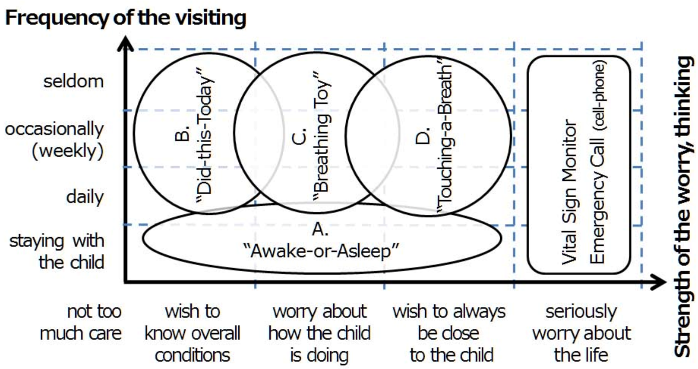

Fig. 3. Individual prototype matches different situations of a hospitalized child and the family

The participant indicated positive responses for this type of communication-supporting environment and, provided the most positive response to the "Touching-a-Breath" that emphasized tangible communication through touch. The results suggested that individual prototypes are appropriate for different situations (Fig. 3). There was not one prototype that was appropriate in every situation. For example, “Awake-or-Asleep” seemed helpful in situations in which families stayed at the hospital with their child.

4 Concluding Remarks

The present paper presented an integrated approach that combined a qualitative study and development of a new communication supporting environment for geographically distributed family members, particularly between hospitalized children and their families. Our process consisted of field interviews, qualitative analysis, establishment of design principles, and development of peripheral communication prototypes.

Two in-depth field interviews were conducted for both in-hospital school teachers and the mother of a child hospitalized on a long-term basis. The qualitative analysis provided us with deep insights into the organization of the interactions between a hospitalized child and the family. On the basis of the analysis results, we established a set of design principles and developed four prototypes of different types of peripheral communication. In our initial field evaluation, the participant provided the most positive response for “Touching-a-Breath,” which emphasized tangible communication. The design principles played an essential role of splicing heterogeneous processes of qualitative study and the development of technology prototypes.

Our future research involves further field studies, including evaluations, enhancement of prototypes, improvements of quality in qualitative research [11], and refinement of the design principles. There still exists a *gulf* between the outcome of qualitative research and basis for the design of user experiences [20]. Our challenges involve methodological enhancements to bridge this gap in the research and design.

Acknowledgments. This work was supported in part by JSPS Grant-in-Aid for Scientific Research (#23300263). We thank all our participants, who provided us with insight into the individual styles of communication between a hospitalized child and the family members. We thank Chigusa Honda, Asuka Noguchi, and our laboratory members, who devotedly supported our field studies.

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Development of a Chest X-ray Examination Support System for Foreigners Using a Personal Digital Assistant

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Abstract. According to the report about inconvenient for foreigners, there are a lot of problems when communicating with medical staff in the medical service. Considering the spread of digital personal assistants and mobile phone, we proposed a communication support system using these devices for foreigners, which would be able to be easily used in medical service. In this paper, we developed the communication support system for X-ray examination, especially. From the experimental results, we concluded the effectiveness of our system because necessary time for X-ray examination was shortened when using our system.

Keywords: Quality of life and lifestyle, X-ray examination, Communication, PDA, Mobile phone.

1 Introduction

From the Ministry of Justice in Japan, the number of foreign registrants and the foreign immigrants are approximately 2,130,000 and 9,440,000, respectively in Japan. It was reported that most awkward place for foreign people was a hospital because they did not communicate well with medical staff in Japanese from the Agency for Cultural Affairs in Japan. However, there were few trials which could improve communication quality for foreign people in the medical activities.

Incidentally, most awkward place was a hospital too for the hearing impaired. We are developing a chest X-ray examination support system for the hearing impaired [1]. In our system, instructions for X-ray examination would be displayed on a screen of personal digital assistant (PDA) such as iPhone because the PDA became more popular recently in the world. Therefore we decided to develop a chest X-ray examination support system for foreigners by using the results for the hearing impaired.

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S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 285–290, 2013.

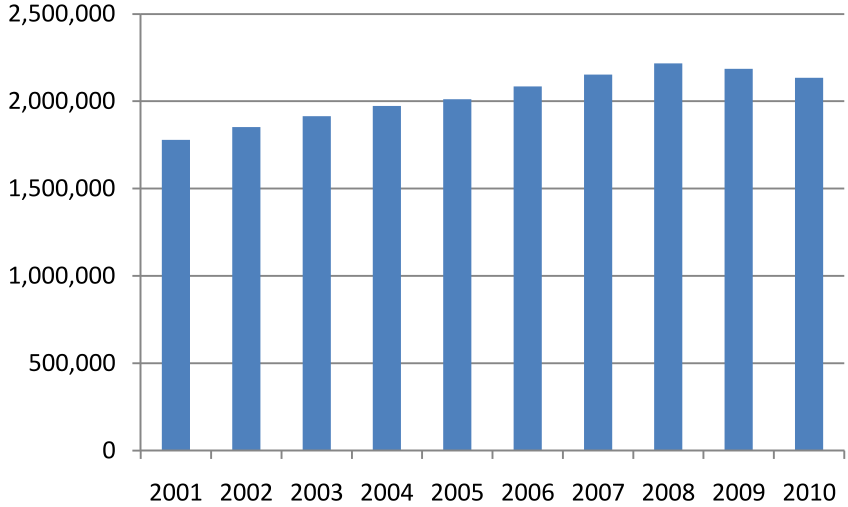

Fig. 1. Annual number of foreign residents in Japan

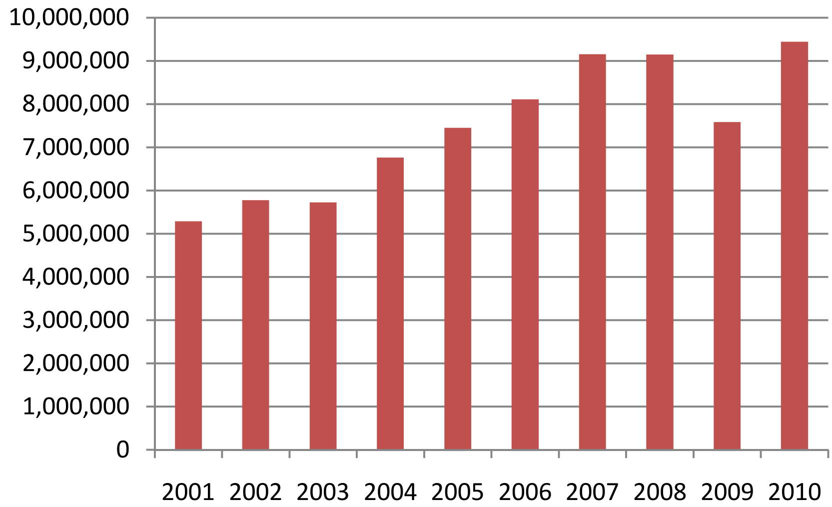

Fig. 2. Annual number of foreign visitors in Japan

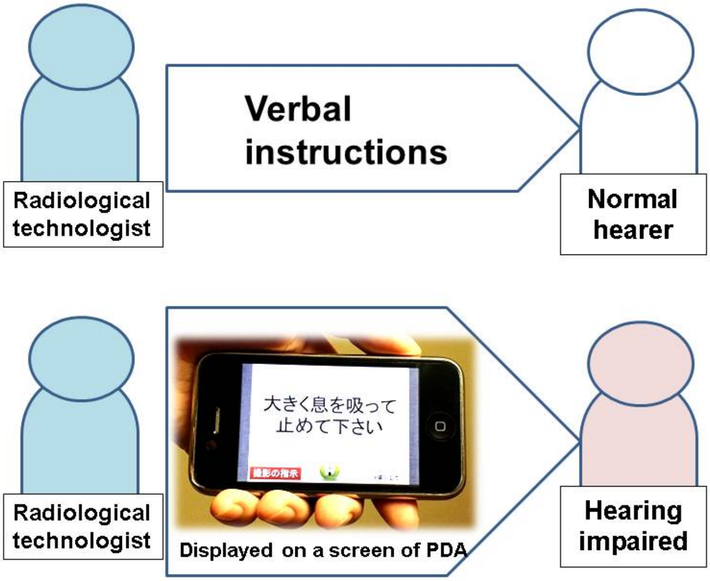

Fig. 3. Overview of our system for the hearing impaired

2 Outline of Our System

When hospitals or medical staff did not prepare communication method with foreign patients, if the foreign patients had their own PDAs which could display examination instructions, the patients would take medical examination by following the instructions of medical staff.

Figure 1 shows the outline of our system. Our system would have the following steps: (1)making presentation data in foreign language and data includes phrase/sentence list which are used in the chest X-ray examination in Japan, (2)uploading the data to our Web page, (3)letting the foreign patient download/install the data to his/her own PDA, (4)asking the foreign patient to bring his/her PDA to the hospital, (5)to hand the PDA to a medical staff(radiological technologist), (6)displaying an examination instruction on a PDA screen by medical staff in a hospital, (7)the foreign patient should obey the instruction which is displayed on his/her PDA.

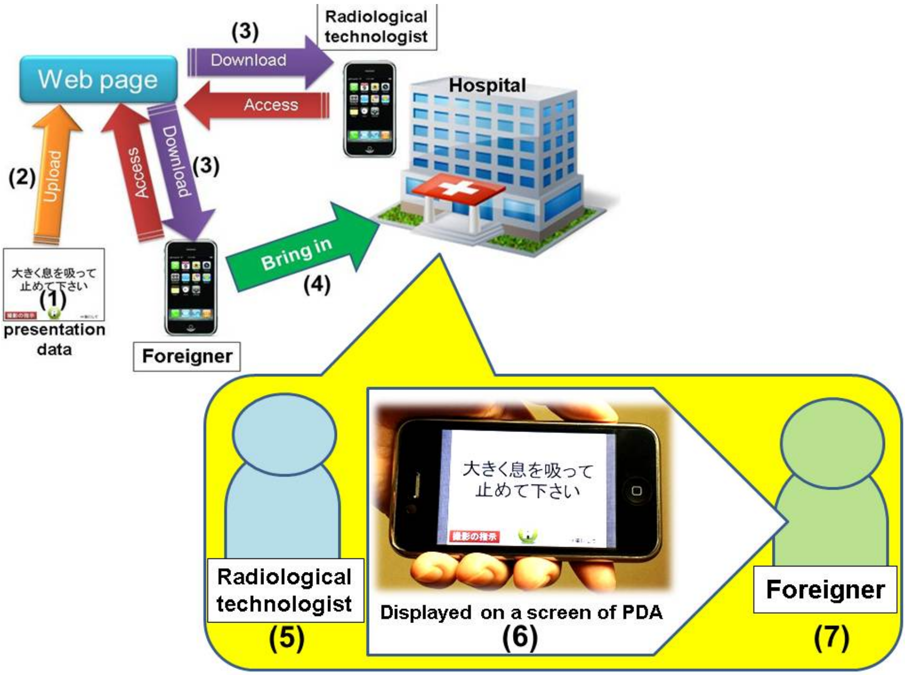

Fig. 4. Overview of our system for foreigners

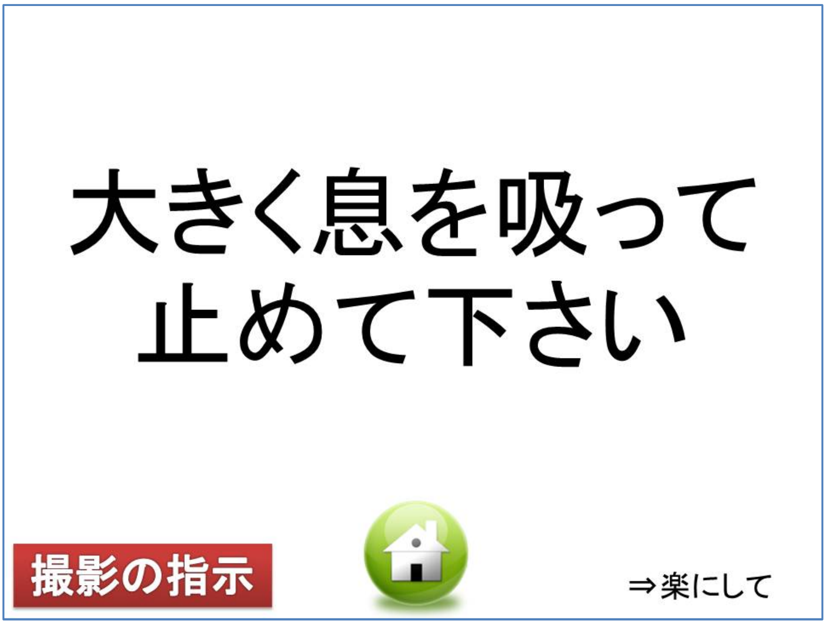

Fig. 5. An example of display data in Japanese

Fig. 6. An example of display data in English

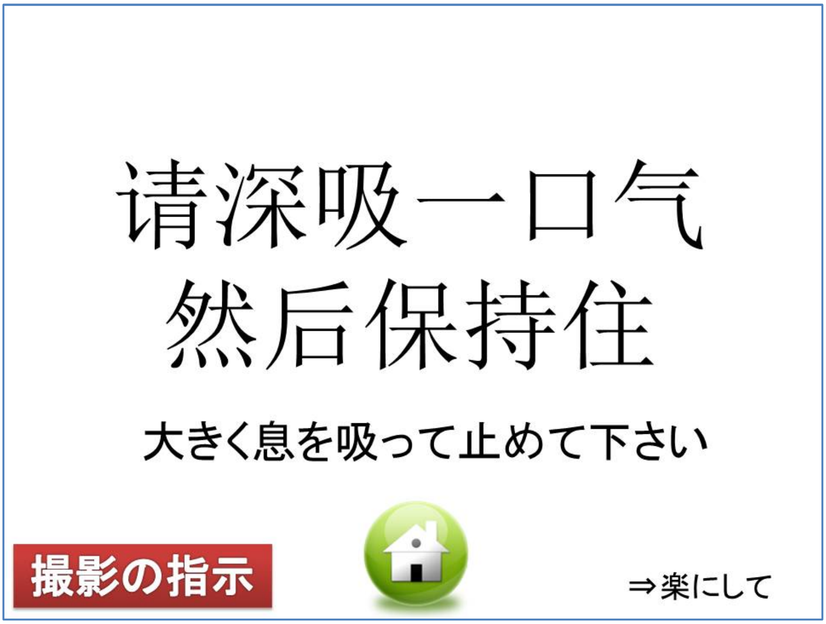

Fig. 7. An example of display data in Chinese

3 Expected Advantage of Our System

1. The examination instructions are almost same in a medical examination. Then, if one example of presentation data is completed, our system would be available after modifying small correction in order to adjust to the different instruments or different examinations
2. The hospitals or medical staffs do not need preparation for foreigners because PDA is brought by the foreign patients themselves.
3. The PDA is small size and light weight. Also, the instructions are easily legible because of back light if examination room is dark.

4 A Future Plan

We are developing this system and evaluation experiment to effectiveness of our system will be executed. Then, in the oral presentation, we are going to reveal usefulness of our system for the foreigners from the experimental results.

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Development of Screening Visual Field Test Application that Use Eye Movement

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Abstract. The purpose of this study was to develop a screening device for the early detection of glaucoma. We evaluated our proposal system by comparing the results obtained by using the proposed system and Humphrey Field Analyzer (HFA), which was commercially available visual field measurement device. Quantitative evaluation of the proposed system and HFA visual field test results, and calculating the correlation coefficient, we were able to obtain a more moderate positive correlation. This study suggested that the proposed system was potentially useful as an alternate screening device for the detection of the early stage of glaucoma.

Keywords: screening, glaucoma, eye movement.

1 Introduction

With the recent aging of the population the prevalence of glaucoma has become a major ocular diseases. According to the latest epidemiological surveys[1] a random sampling of 4000 persons aged 40 and order shows the total glaucoma prevalence of 5.0%. Glaucoma is not usually accompanied by subjective symptoms, thus when a patient first recognizes visual deterioration or visual field loss, the disease has already developed in many cases. Therefore, early detection and treatment are of great importance for preventing serious stage of glaucoma based symptoms[2]. Under such circumstance, a visual field examination system for screening has been explored to test visual field rapidly [3].

In clinical practice, the Goldmann perimeters and Humphrey Field Analyzer (HFA) are widely used. However, these devices require 10 to 20 minutes to complete

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 291–300, 2013.

the examination for each eye. In addition, patients need to fixate their eyes at the center of the display throughout the test. This test procedure affects the patient's concentration [2, 4, 5]. Furthermore, it is difficult for children and elderly people to understand the instructions properly, and to press a button as soon as they recognize the target. When patients forget to press a button, or when considerable delays occur, the visual field is inaccurately estimated, which degrades the reliability of the test result. Due to the above problems, conventional visual field examination systems are considered unsuitable for screening. In this study, we propose a method of visual field examination using overlapped fixation patterns obtained from voluntary eye movements that occur when a target is detected. The goal of this study is to facilitate the proposed system with a diagnostic performance level suitable for screening for visual field loss derived from glaucoma. Our previous studies[4] have already shown the possibility of detecting an abnormality of glaucomatous visual field by the proposed system. However in the recent field of medical examination, the evaluation emphasized on the distribution of visual sensitivity rather than quantitative visual field has been performed because Quality of vision (QOV) has become more important in the recent field of medical examination. Sensitivity distribution is an index that represents the quality of the "visible area". Accordingly, we introduce the method of presenting the test target that changes the contrast of brightness for the improvement of the current system as the next stage of the proposed system, This modification would make the system possible to obtain visual sensitivity by knowing the responses with different contrast of brightness. It is necessary to ensure that misalignment of test position should be minimized in order to evaluate the distribution of visual sensitivity.

Therefore, switching from the conventional method which presents the test target determining the absolute position in advance, a new method (online-offset) for determining the position of the test target by the relative position based on the position of line-of-sight was proposed. It is expected that this modification will suppress the influence of the displacement that occurs during the inspection. In order to verify the practicability of the proposed system, a set of experiments was conducted with eight glaucoma patients and two healthy subjects. By conducting the evaluation experiments the current study focused on verifying whether the proposed system provided the information that have been asked in clinical site, which provides the proposed system offers enough visual field with a certain sensitivity compared with those by the HFA, as a traditional perimeter.

2 Proposed System

2.1 Principle and Configuration of the Proposed System

The method of visual field examination using the proposed system consists of determining the visual field by the continuous occurrence and detection of voluntary eye movements with large saccadic magnitude. In this method, voluntary eye movements are used to confirm whether a subject recognizes a target appearing while he/she is looking at a fixation point. The relative positions between the fixation point and the target recognized by the subject are superimposed on the eye movements; thus, the visible and invisible areas are determined and the subject's visual field is evaluated. As shown in Fig. 1, the proposed system is composed of a target presentation screen (Dell 3008WFP, display resolution 1920 × 1200 pixels), a visual field detection device (Tobii X120, spatial resolution 0.2°, fixation point error 0.5°, sampling frequency of eye localization 120 Hz, sight line position error due to head movement 0.2°) [7], and a control PC (Dell). The control PC is used to collect eye position data and process them in real time, and to present the target. Since the subject's sight line is detected by the detection device, the visual field can be evaluated by sight line tracking, and only natural sight line movements are used for examination. In addition, there is no need for head fixation so long as the distance to the display is maintained, because the proposed system uses the principle that when a subject tracks a target, the spatial characteristics of the visual field remain unchanged. In contrast to conventional perimeters, in the proposed system, a subject performs a sequence of eye movements that his or her sight line matches with the recognized target. In the course of examination, the target to which the sight line moved is treated as the new fixation point (center of the visual field) (see Fig. 2). Due to this treatment of recognized targets as new fixation points, visual field examination is possible by using overlapping sight line data, even though the sight line shifts during examination. In the existing visual field test systems, it is difficult for subjects to concentrate on a certain fixation point during the examination; in addition, it is difficult to explain to some subjects (mainly children and elderly people) how to use the buttons for confirmation of target recognition. In contrast, in the proposed system, the visual area is determined by the accumulation and superposition of fixation patterns so that the fixation point is placed in the center. The target to which the sight line moves is treated as a new fixation point, and target recognition is detected by eye movement. As a result, a subject must concentrate for only a short time, and no button pressing is necessary. In the proposed system, the sight line is shifted during the examination, which promises relatively easy visual field testing even for subjects who have difficulties in understanding the instructions.

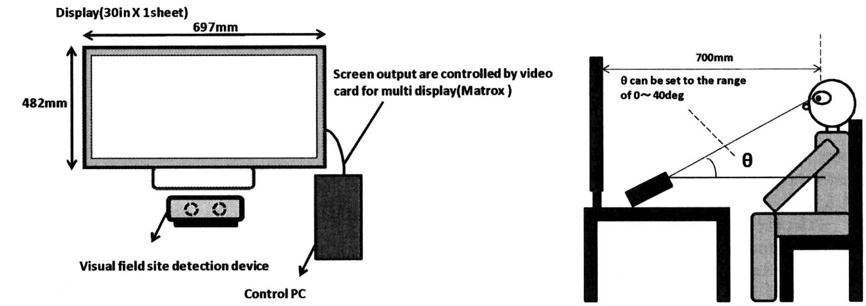
2.2 Procedure of Visual Field Examination

The procedure of visual field testing using the proposed system is as follows.

1. The subject gazes at the fixation point presented on the display. After a certain time period, a target is presented within a designated visual field.
2. If the subject recognizes the presented target while looking at the fixation point, the subject's sight line moves to the target position.
3. When the subject moves the sight line to the presented target, the target position becomes the new fixation point, and the previous fixation point is deleted.
4. The new fixation point appears for gazing, and the procedure returns to step (1).

A subject is asked to recognize the targets and to move the sight line accordingly while repeating steps (1) to (4) (see Fig. 3).

When the subject cannot recognize a target, the target is assumed to be located within an area called scotoma. In this case, the subject cannot recognize the presence of the target and continues to gaze at the fixation point. After a certain period of time, the fixation point is disappeared to inform the subject that the target has been presented a location where the subject cannot recognize. The subject then moves the sight line to search for the target, and fixes his gaze on the target once it is found. After a certain period of time, the target becomes the fixation point and the examination is continued (see Fig. 4).



(a) Set up for the proposed system

(b) Side view of the proposed system with a subject

Fig. 1. Proposed visual field evaluation system

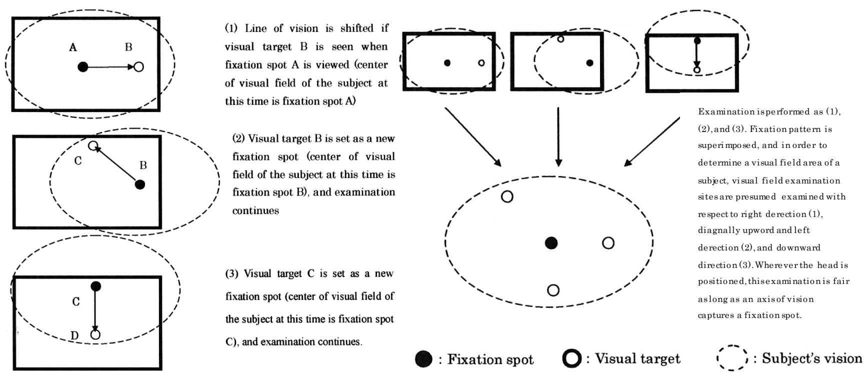


Fig. 2. Mechanism of the proposed screening system

2.3 Detection of Visual Field Defect Areas by Sight Line Movement

The above procedure is for when there is no vision abnormalities. If the test target was presented abnormal visual field area, it is not possible to visually recognize the test target when the subject gaze the fixation point. Therefore, if the visual line stationary the fixation point above 2500 msec, proposed system makes to eliminate the fixation point to inform the test target is presented to the subject. If the fixation point

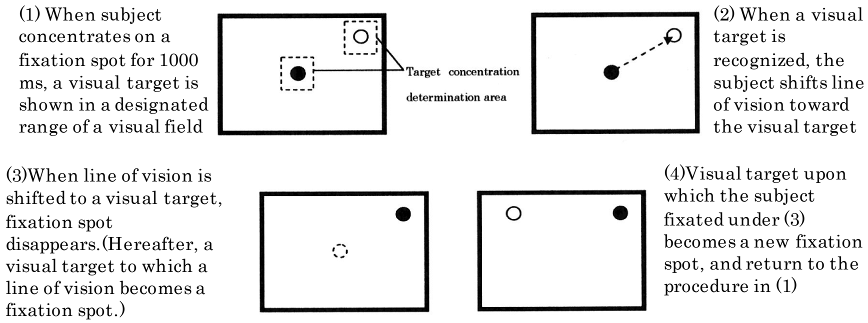


Fig. 3. Visual field test procedure for proposed system

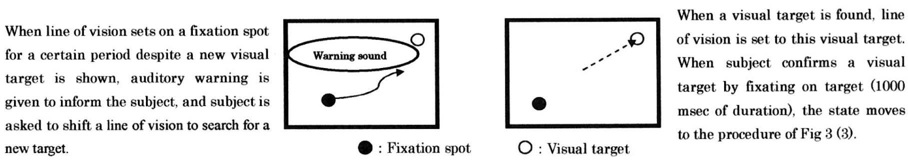


Fig. 4. Subject's action and subsequent system responses when a target was invisible due to the visual field defect

is lost, the subject is searched test target which is presented on the display. When the subject gaze the target over 1000msec, it becomes a new fixation point. After that, the procedure will return to the normal inspection specification.

3 Experimental Evaluation of Proposed System

3.1 Objective of Experiments

The purpose of this study is that the results obtained in the experiment using the proposed system can demonstrate certain accuracy as the existing perimeter. Secondary, it is verified that the system can offer the information about not only quantitative visual field but also visual sensitivity distribution. By completing the two purposes described above, the possibility of introducing this system in clinical field was clarified by offering the exact position of the visual field abnormality and progress of the symptom as a material for determination of glaucoma at the time of initial diagnosis to the physician.

3.2 Experimental Subjects

The subjects are eight glaucoma patients (for early stage glaucoma four subjects; four middle-stage glaucoma subjects; age: 52 to 80 years old; eyeglasses: none), and two normal subjects.

3.3 Experimental Procedure

The experimental procedure is described below.

5. The subject covers the untested eye with an eye patch.
6. The subject is seated so that his or her sight line is perpendicular to the display at a distance of 700 mm.
7. Calibration is performed to match the eye position detected by the system with the actual eye position.
8. The experimenter presents the test screen to the subject, and visual field examination is performed as described in the previous section.

The experimental setup is illustrated in Fig. 1.

3.4 Experimental Conditions

The experimental conditions are shown in Table 1. A total of 10 subjects (Two with normal sight and, eight patients with glaucoma) participated in the study. The stimulus used in the experiment is shown in Fig.6. In Fig.6, the numbers in brackets show the luminance contrast ratio to white background. For the first time, a visual target shown in Fig.8 (1) is presented. If the subject recognizes the target (1), the next target becomes (2).The second stimulus is (3) presented if (1) was not visible. Changes in new target dependent upon the result of recognition of the previous target would generate the information about sensitivity distribution more clearly compared to the previous testing scheme. The position pattern of the target appeared on the display was referred to those used in HFA, as shown in Fig.5.

Table 1. Experimental condition

Visual Distance	700mm
Subject	10(Normal eye 2, Glaucoma patient 8)
Display Resolution	1920 × 1200 pixel
Display Size	645 × 400 mm
The size of the target	0.583deg
Inspection points	58

4 Experimental Results

Topographic displays for the HFA are drawn using the measured sensitivity values (unit: dB), which is very different from the principle of the proposed system. Thus, in this study we considered the practicability of the proposed system by comparing the trends in the topographic displays for all ten subjects, and examining the average retinal sensitivity in the HFA clusters and the average recognition point in the proposed system. In order to evaluate quantitatively the results obtained by the proposed system, we considered the areas used in the glaucoma hemifield test (GHT), one of Anderson's criteria for early glaucomatous visual field defects (Fig.8). Since the early defects occur in either the superior or inferior hemifield, in the GHT both hemifields are divided into five symmetrical zones (clusters) within 30° along the retinal nerve fiber paths, and the asymmetry between the hemifields is detected. In locations corresponding to the five symmetrical zones, the average retinal sensitivity in the HFA and average recognition rate in the proposed system were calculated and normalized as follows, for use in examining the correlation between the values:

- Average retinal sensitivity in HFA cluster = (Total of retinal sensitivity in cluster)/(Number of test points in cluster)
- Average recognition point in proposed method = (The sum of the recognition point in cluster) / (Total recognition points in cluster)

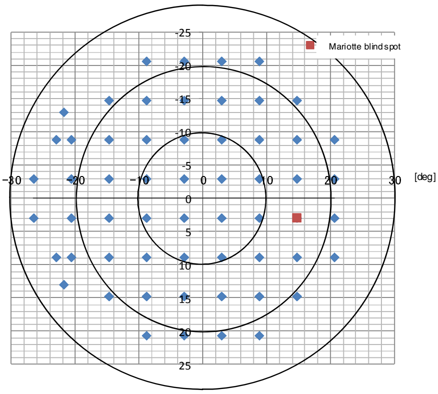


Fig. 5. Detailed location of tested area of visual field (right eye)

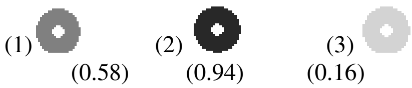


Fig.6 Visual target used in the experiment

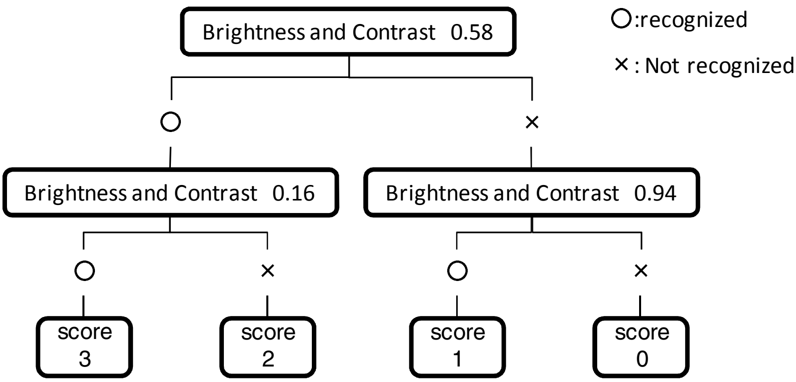


Fig. 6. Method of assigning scores classified by the result of the previous testing target

In this proposed system the recognition scores should be assigned according to the condition whether or not the target can be visible. Therefore four levels of scores were given dependent on whether a visual target was visible, as shown in Fig.7.

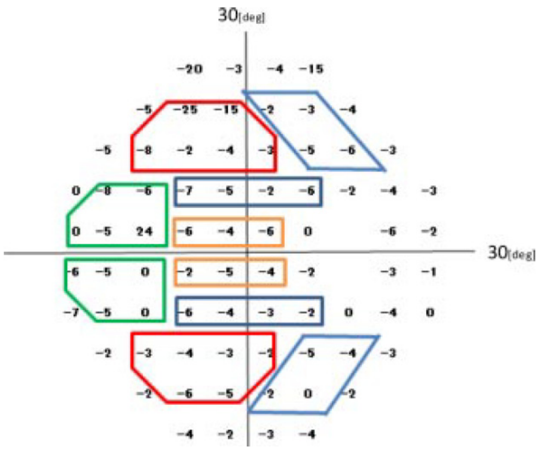


Fig. 7. Patterns of glaucoma hemifield test (right eye, numbers in the patterns are arbitrary)

It was validated that the proposed testing scheme can express the sensitivity distribution if there was a correlation between retinal sensitivity as the result of the existing perimeter and recognition scores as the result of the proposed system. As a result of the inspection, 5 out of 10 subjects failed to complete the visual field test because eye movement detection data recorded by eye-tracker were not enough for generating visual field this time. Fig.9 shows the test results of the subject H who was able to perform the inspection, as an example. In addition, Fig.10 shows the test result of subject H by using the HFA. As shown in Fig.9, Mariotte blind spot was detected successfully in a visual field test using the proposed system. In addition, the proposed system captured the characteristic visual field abnormality, which can be seen from the nose, extended to the center of visual field. Table2 shows correlation coefficient of average recognition scores in the cluster by the proposed system and the average retinal sensitivity in the HFA cluster for each subject.

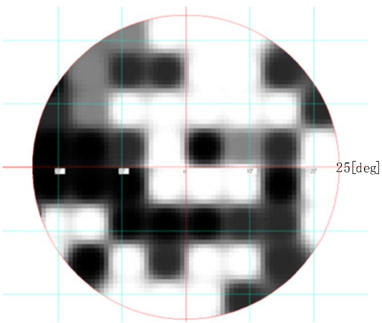


Fig. 8. Result of proposed system

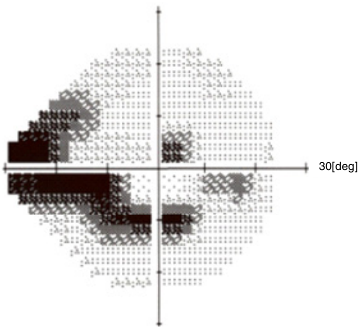


Fig. 9. Result of HFA

5 Discussion

When evaluating the proposed system, we compared visual defects detected by the HFA used in clinical site and by the proposed system; in particular, we checked whether Mariotte blind spots were recognized with the proposed system. However, in the HFA tests used in clinical site, the reliability of the test results may be degraded when the patients forget to press a button, or when the reaction time produces large delays. Therefore, the HFA examination of the visual field does not necessarily produce correct results. We are able to determine that visual field abnormality with the proposed system was observed for the area that is determined to be abnormal visual field in HFA that is existing perimeter from Fig.9 and Fig.10.

Table 2. Coefficients of correlation between retinal sensitivity of HFA and recognition scores of proposed system as evaluated by GHT clusters

Subject	Correlation coefficient	Degree of correlation
H	0.89	strong correlation
G	0.76	strong correlation
A	0.68	moderate correlation
E	0.57	moderate correlation
J	0.56	moderate correlation

In addition, this examination was conducted in four levels and each level had different colorings, for the evaluation of the progress of the visual field abnormality. Therefore, the results obtained by evaluation experiments are observed that the grayscale display is similar to data obtained in the HFA. However, there were cases that are determined to be abnormal in a position that is not abnormal position with proposed system. It is considered possible that occurred because the stimulus that determined the position based on line of sight position. Resolution of line of sight position is supposed to be the fixation point error of less than 0.5 deg according to the specifications of the device. However, because they were aged 50-80 in this experiment, there was a possibility that the participants have difficulty in holding the eye position although they believed they fixated a certain point. This is due to the fact that the target is difficult to see because subjects become watery eye due to weakening of the function of the emission tear. Therefore, it is considered to have been determined to be abnormal to normal site since the line of sight position shifted by defective fixation from the fixation point after presenting the test target. Further, our proposed system does not require the base jaw in order to achieve the test that subjects do not hold as much as possible in terms of screening. Therefore, it is considered possible that face moved when subjects were gazing at the fixation point. However, since the purpose of this study is to develop visual field test system for screening applications, it is important to know the progress of characteristic visual field abnormality place. Therefore, since it is possible to detect the characteristic abnormal visual field locations, the proposed system can be fully utilized. There was marginally high correlation between retinal sensitivity of HFA and recognition scores of proposed system for all subjects properly tested. This was probably due to improved fixation accuracy by applying online-offset technique by reducing misalignment of inspection position. Because there was a more moderately positive correlation even for subjects with normal eyes, the proposed system has a potential to evaluate the quality of the appearance of the visual field properly even for people with normal eyes. It was found that the proposed system did not respond further in spite that the subjects gazed into a test target in the case where the examination was terminated. This is the case in which the subject with a medium stage of glaucoma may have encountered quite often since such patient tended to gaze at the target in erroneous way. This type of error cannot be detected by the eye tracker used in this experiment. The tracker in this study estimates the eye position by detecting the sight position in the basis if the position where Purkinje image is generated. However, there is a case that the glaucoma patients with advanced visual field abnormality tend to gaze at a target by an eccentric vision, the position of line of sight is shifted accordingly to the position by an eccentric vision.

6 Conclusions

We have proposed a visual field examination method using voluntary eye movement to determine the visual area. In order to evaluate the applicability of the proposed system to visual field screening, we compared the results as visual field examination of glaucoma patients obtained by the proposed system and by HFA. As a result, glaucomatous visual field defects can be detected by using the proposed system. It was also found that the system should be improved more versatile because there was a case when it was not possible to complete the inspection by the progress of symptoms and by some individual characteristics.

Acknowledgements. This work partically supported by JSPS Kakenhi (24370103, 24657182) and Ecological Interface Design Research Group, ORDIST, Kansai University.

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Identification of Agency through Virtual Embodied Interaction

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Abstract. To examine the identification of “social actors,” we created an experimental environment to observe how people interpret the behavior of others. Our experimental environment, which physically provided interaction between a human and a computer, was a media system that connected two sides of the experimental environment to a computer network. In our experiment task, participants used our system to determine whether the other party was a human or a computer. In this study, we regard the attribution of agency toward the behaviors of others as a sign of agency identification. Our experiment results suggest that the human identification of “social actors” is induced by the interaction between the target entity and the subjects.

1 Introduction

People have the ability to regard anything around them as “social actors.” In this paper, we define “social actor” as an entity that possesses the intellectual ability to form a relationship with humans [1]. Of course, humans are the most common social entity that possesses intellectual ability and can form relationships with others. However, this idea is not always applied even though the “social actor” is a human. The identification of a “social actor” to a human depends on the individual’s psychological attribution by which one identifies others as “social actors.” This mental activity can be shown in urban situations where people ignore others and treat them as walking obstructions. The identification and attribution of “social actors” are determined, not on their properties but on their actual behaviors during interaction.

The above analysis suggests the following question: How does interaction with others affect their identification when they bestow the label “social actor” on others? We carried out a simple psychological experiment to explore this question.

2 Social Actor

2.1 Communicable Relationships

We define a “social actor” as an entity with agency that can form a relationship with humans to exchange significant information.

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 301–307, 2013.

Agency is the property of an agent and contains the following features [2]:

Intentionality
The agent behaviors are purposive. The agent aims to achieve its purpose.

Autonomy
The agent behaves autonomously to achieve its purpose.

Rationality
The agent rationally and suitably behaves to achieve its purpose in any situations.

Individuality
The agent exists individually and acts respectively.

Interactivity/Sociality
The agent interacts with others to effectively achieve its purpose.

To form a relationship to communicate between humans and agents with such features, humans must understand the purpose behind an agent's behavior. However, such human understanding does not need to be consistent with the agent's actual inner status. The purpose of the agent's behavior, which the human supposes under this impression, does not necessarily agree with the agent's actual mind when the human is directly interacting with the agent.

In this paper, the concept of communication is different from the concept of interaction. Interaction means a state where mutual action is organized with or without understanding the purpose or the intention of an agent's behaviors. Communication denotes a state that can interpret the agent's behavior based on the understanding of an action's purpose and intention after assuming the establishment of interaction with it.

2.2 Communication with Social Actor

When an interaction partner's identity is unknown and provides no visual or auditory clues, such as appearance, do people identify the partner as a "social actor"? Suppose they identify such an unknown entity as a "social actor." What kind of interaction will be carried out between the two participants? In other words, when people identify the unknown entity as a "social actor" and form a relationship to communicate with it, what kind of interaction will be carried out? To explore this research issue, people interacted with unknown entities to solve the following problems:

1. Does the interaction partner possess agency?
2. When the interaction partner is an agent that possesses agency, what is the purpose of the agent's behaviors?
3. How would the agent's behavior be interpreted to achieve its purpose?

Communication with the agent is established in phase (3), indicating that people can interpret agent behaviors based on an understanding of their purpose and intention.

3 Experiment

3.1 Purpose

In this section, we explain our experiment that examined whether people identified the agency through a simple interaction environment, which was described in Section 2.2, as the first phase of agency observation. We expressed a human whose identity and agency were unknown as a shadow that virtually reflected its physical position and movement to the participant. Then we observed the interaction between the participants and the shadow to explore whether agency identification occurred when the shadow's movements, which symbolized the movement of the unknown entity, interacted with the participant.

3.2 Method

We made two experimental conditions and equally assigned 30 university students to each condition. The only instruction given to them was that they were allowed to move freely within the 1.2 x 0.9 m floor.

In the human condition, the human acts as an unknown entity and is imaged as a 20-cm diameter, circle-shaped shadow. The shadow's position corresponds to the position of the performer's waist, which was measured by Kinect sensors. As shown in Fig. 1, the performer's movements are reflected in a shadow that appears in the participant's room. The performer looks at the display that shows the participant's position and her own relative position.

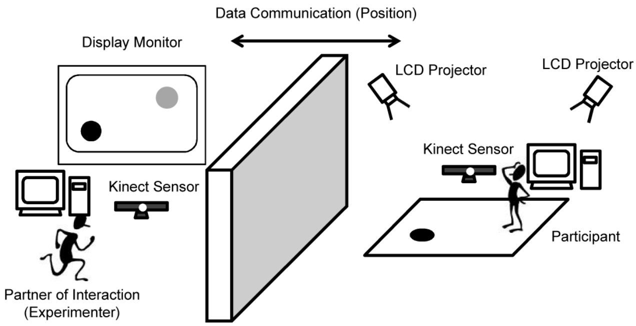

Fig. 1. Settings of the experiment

Fig. 2. Scene of interacting with the shadow

In the program condition, the human who is acting as an unknown entity in the human condition is supplanted by a computer program that determines whether the shadow is an unknown entity based on the current participant's position and decides its position with an algorithm and moves randomly between 0-800 mm/s.

The participants of each experimental condition freely interacted with the moving shadow for three minutes (Fig. 2) and then answered questionnaires.

3.3 Observed Data

We observed and analyzed the following data:

A) *Behavioral data*
- Log data of participant position (every 100ms)
- Log data of shadow position (every 100ms)
- Interaction video

B) *Questionnaires*
- Participant impressions about the agency (Human / Computer / Undistinguished)
- Participant impressions about the shadow (animacy / intentionality)

3.4 Results

Fig. 3 shows the results of the participant impressions about the agency through questionnaires after the interaction. Nine of the fifteen participants in the human condition could not identify the agency by observing the shadow behaviors. Four of the fifteen participants thought that the shadow behaviors were controlled by a computer program. Only two participants identified the agency from the shadow behaviors.

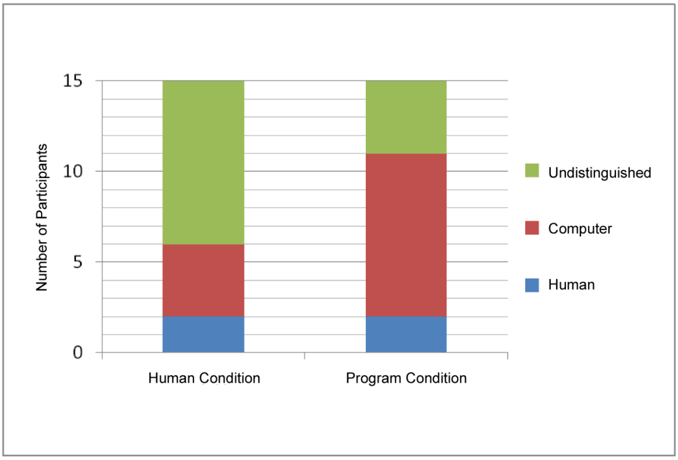

Fig. 3. Result of identification

The results of the program condition showed that nine of the fifteen participants correctly realized that the shadow behaviors were controlled by a computer program. Two participants identified the agency, and four participants could not identify it by observing the shadow behaviors.

Fig. 4 shows the number of movements in each case of the participant impressions concerning the agency. We found significant results when the participants identified the agency (human condition). They actively moved and interacted with the shadow.

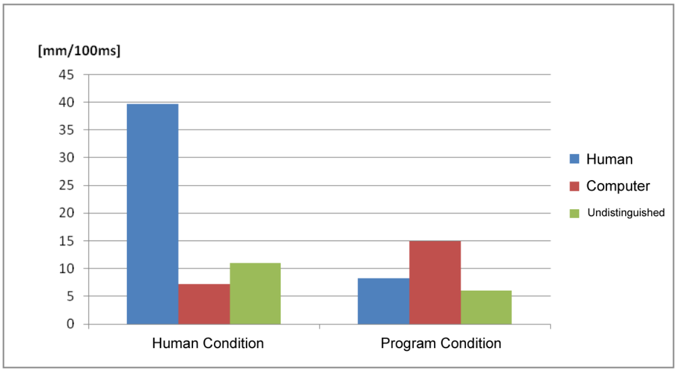

Fig. 4. Result of behavioural data

3.5 Considerations

As shown in the human condition results, the participants who identified the agency of the shadow significantly recognized the shadow behaviors and actively interacted with it, although their number was few. They correctly identified that their interaction partner possessed agency, indicating that they not only visually observed the shadow behavior but also physically and actively interacted with the shadow to verify the agency (Section 2.1).

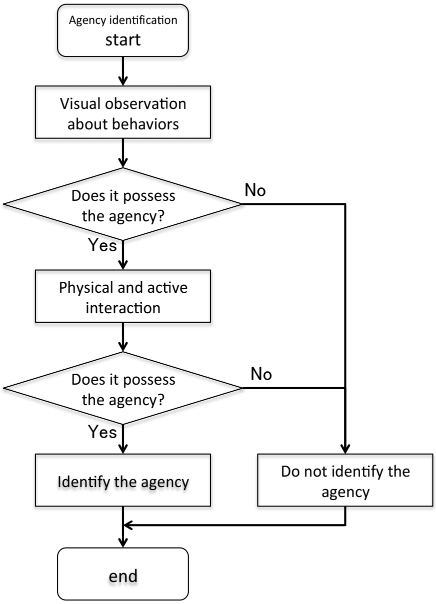

Fig. 5. Flow of agency identification

On the other hand, as shown in the results of the program condition, most participants did not identify the agency through the shadow behaviors. They assumed that the shadow movement was controlled by a computer program. This supposition was carried out by limited interaction and visual observation, not by physical and active interaction.

Agency might be identified as the following process (Fig. 5).

1. The participants carried out agency identification by visual observation.
2. If they intuitively identified the agency, they interacted more actively to verify their supposition that their interaction partner possesses agency.
3. If they did not identify agency, they believed that their interaction partner was a machine.

4 Conclusion

In this study, we examined whether people can identify agency through a simple interaction environment. Our result indicates that agency identification is actively achieved by observation and interaction steps.

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Human Support System for Elderly People in Daily Life

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Abstract. This report proposes a new support system that allows elderly people able to live with a sense of security without the help of other people. In this system, by using sensors, it is possible to watch closely the condition of elderly people from a distant public institution. Furthermore, the significant information to maintain their physical condition is presented by this system. Then, according to an experiment using this system, the possibility is made clear that this system would be useful for the support of elderly people.

Keywords: Elderly, Support system, Welfare technolog, Remote sensing, Unwearable sensing, Human motion.

1 Introduction

The number of elderly people is rapidly increasing in both developing and developed countries. It is necessary to establish methods for taking care of many elderly people through a social system. There are many reports about characteristics of human motions in daily life [1-3]. However, there are only a few reports on measurement of elderly people's behavior in daily life situations [4-9]. To establish more adaptable care systems for elderly people, it is important to attempt measuring and analyzing human behaviors and motions in daily life.

In our laboratory, we study the development of support systems for the elderly people. This paper proposes a new support system that analyzes human behaviors and motions and detects a change in the physical condition of an elderly human in the house. It is thought that it is important to research elderly people's behavior in daily life and investigate it thoroughly for developing and establishing a support system.

2 System Architecture and Questionnaires

The new support system is a Living Situation Monitoring System the concept diagram of this system is illustrated in Figure. 1. The system is fundamentally composed from sensor units, a controller unit and a supervisor unit. Several sensor units and a controller unit with two antennas were placed in the house of solitary elderly people.

Also, this support system has communication tool. This tool was used when Health Management Center send the information of local community's event to

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 308–314, 2013.

elderly people. Figure. 2 show operation screen on side of Health management center when they send information. Figure. 3 show operation screen on side of Elderly people.

The sensor units consisted of four types of sensor: a pyroelectric infrared sensor, a magnetic door sensor, an electric current sensor and a light sensor. For example, a pyroelectric infrared sensor was able to perceive any human motion by detecting the IR emission from a human body. Also using an electric current sensor, it was possible to record some actions in a human life like turning on/off the switch of a television, an electric heater, and so on. Using these sensor units, human behavior could be detected. These data were transmitted to the controller unit using a wireless telecommunication method. In the controller unit, these data were analyzed in order to check the physical condition of an elderly human in the house. Several sensors detected human motions in real time, and the detection results were stored in a controller unit. Furthermore, all data in the controller unit were sent to the supervisor unit. In the supervisor unit, the data were classified into each subject's database and were accumulated. A characteristic pattern for each person, including time series variation of detected values, was extracted from each person's data using only the pyroelectric infrared sensor.

As the new system was developed, preliminary experiments were performed to examine detection accuracy. The subjects were eight elderly people who lived in solitude away from their family.

In addition, questionnaires were developed to understand the elderly people's life style and validated. In the first questionnaire, there were about 70 questions about their daily life everyday for a month: wake time, bedtime, eating time, times of going out, and so on. In the second questionnaire, subjects were told to list every night what they actually had done on that particular day.

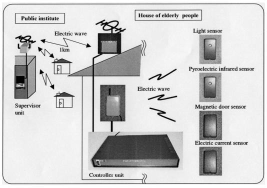

Fig. 1. Concept of the monitoring system of living situation

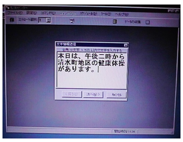

Fig. 2. Operation screen on the side of Health Management Center

Fig. 3. Operation screen on the side of Elderly people's house

3 Results and Verification Experiments

3.1 System Architecture and Questionnaires

Figure. 4 shows detection results by pyroelectric infrared sensor with the characteristic pattern which was transmitted back to the controller unit. It was possible that, by comparing the measured data using the sensor units, the physical condition of the elderly people could be estimated continuously. As a result, it was possible that the sensors detected human motions like moving from one room to another, and actions like turning on/off the switch of a television.

Figure. 5 show diurnal detection results by pyroelectric infrared sensor. This result show exercise tendency of elderly people on several weeks.

Figure. 6 show number of diurnal use of resting room during daylight, late-evening and first light. It was possible to understand condition of elderly people.

Figure. 7 show result which was time of outing every day.

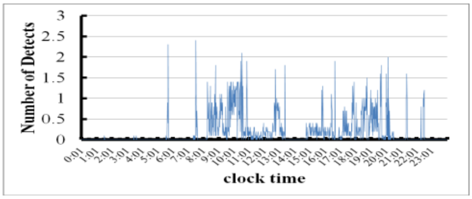

Fig. 4. Number of Detects on one day.

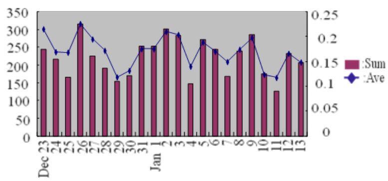

Fig. 5. Amount of diurnal exercise

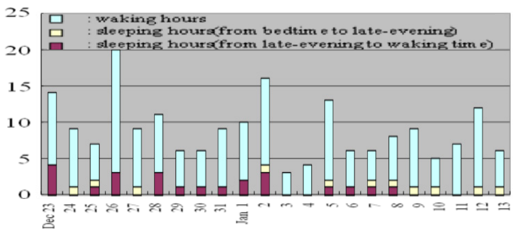

Fig. 6. Number of diurnal use of resting room

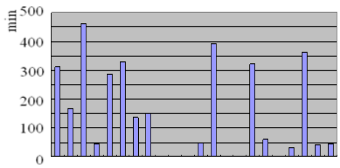

Fig. 7. diurnal behavioral record (time of outing)

From results of questionnaires, there was evidence that the characteristic pattern was influenced by a change of the elderly people's individual life environment. It was necessary that the system could extract and keep in memory in the supervisor unit several characteristic patterns as the environment around the research subjects changed. Also, it was thought that the characteristic pattern was influenced by the change of an elderly individual's weekly life style. Most of the elderly had habits that given behaviors should be carried out on a certain day of the week. For example, elderly people periodically went to the bath of a public institution on particular day of the week.

In the experiments, several sensor units and a controller unit with two antennas were set up in the houses of solitary elderly people. The subjects were eight elderly people and the number of sensor units was about 15 in each subject's house. Figure. 8 shows an illustration of the location of sensor units in an elderly person's house. The number of sensors increases or decreases depending on the number of rooms and the layout of the house. The experiment was carried out in two areas. The center of Takaoka City and Oyama Town were chosen, in order to examine whether the environment around the house was significant or not. In each area, there were four subjects and one supervisor unit. A supervisor unit was located at a public institution within 1 km of the subjects' houses in each area.

In addition to detected results, analysis was carried out with the measured data using sensor units and the results of the questionnaire. Then, using one result of the analysis, we constructed a mathematical model using the neural networks (NN). We investigated other result but one for constructing NN, and realized that the system conjectures one elderly individual's behavior of a day. The analyses using NN software (NEUROSIM: Fujitsu Co., Ltd) were used to conjecture whether subjects were out or at home and were awake or in bed. In analysis of subjects' going out, we used Hierarchical Neural Network including input layer, hidden layer, and output layer. Thirty-five input signals were composed of detection results from five pyroelectric infrared sensors at given times and around 30 minutes by 10 minutes. Output signal was the probability that subjects went out. In analysis of going to bed, we constructed hierarchical NN including input, output and two hidden layers. sixty-six input signals were composed of detection results from five pyroelectric infrared sensors at given times, around 60 minutes by 10 minutes and clock time. Output signal was the probability that subjects were at roost.

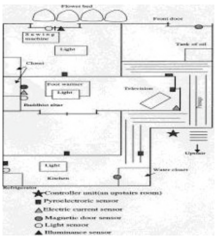

Fig. 8. Disposition of sensor units

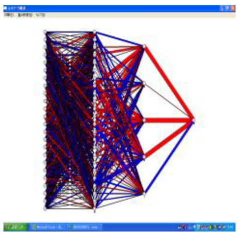

Fig. 9. The example of neural net work model

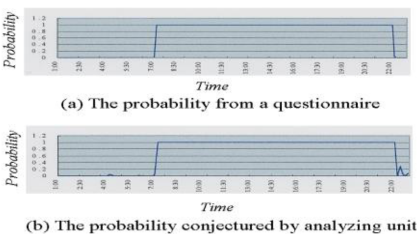

Fig. 10. The probability that a subject has gotten up in one day

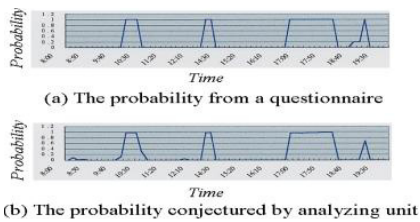

Fig. 11. The probability that a subject has gone out in one day

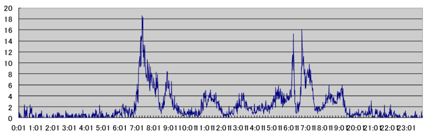

Fig. 12. Good condition data from March 14 to April 29 in 2000

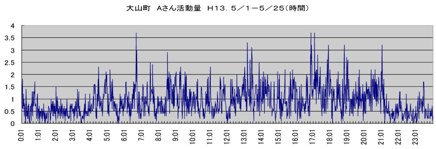

Fig. 13. Bad condition data from May 1 to May 26 in 2000

3.2 Results of Verified Experiments

Figure. 9 is the example neural net work model to analyze for the probability of human behavior based on detections. The neural net work was constructed by three layer model. First layer was containing 24 inputs. Second layer was containing 24 nods. Third layer was containing 2 nods. The neural net work model was learned by data for two month for each subject.

Figure. 10 shows a result for the probability that a subject has gotten up in one day. Upper figure 10(a) shows the probability form only questionnaire. Lower figure 10(b) shows the probability form a neural net work model similar to figure. 9. .In the questionnaire of the same day, the subject got up at 7:10AM and went to bed at 10:00PM. The probabilities were about 0.003 at 7:00AM, 1.000 at 7:10AM, 9.999 at 10:00PM, and 0.009 at 10:10PM. But the probability at 10:20PM was 0.289. Figure. 11 shows one that a subject has gone out in one day.

Figure. 12 shows a summation of detection when a subject's condition was good on one day using the new support system. In this result, the subject starts daily exercise at about 7:00 AM every day. Especially, the behavior pattern was detected after 7:00 AM using the new support system. For another subjects, behavior pattern was detected each subject using the system. These behavior pattern were varied, but the behavior patter was unified by each subject like Figure. 11. And it seems that the various related not environments but subjects. On the other hand, figure.13 shows a summation of detection when the same subject's condition above result was bad. Because this results were recorded just before this subject was hospitalized. In this result, It is not sure when the subject starts daily exercise and shows that the count of detection is lower level than the result of figure. 12, but another behavior pattern was detected using the new support system. For another subjects, behavior pattern was detected each subject using the system. In this figure. 13, the behavior patter is not same to the behavior pattern of figure 12 about the same subject. So, it make sure that a difference between a behavior pattern for good health condition and a behavior pattern for bad health condition was detected using this system. So, it considered that it is possible to make a judgment about elderly people's health condition. It means that the difference behavior patter.

4 Results and Verification Experiments

Using the new support system, it was possible to detect elderly motions in life. The most important thing in this system was to detect elderly ones with non-wearable sensors. In addition, play-out and uplink of detected data were performed by wireless connection between both sensor units and controller unit, and between controller unit and supervisor unit. After experiments, we constructed the neural network, and conjectured elderly motion and individuals' particular patterns. Results from neural network analysis were correlated to detected motions and questionnaire responses.

Recently, many companies have become interested in remote sensing for elderly people's healthcare and conducted remote sensing with wearable sensors [10,11]. But, in this case, there was physical limitation, and the elderly went about their daily life with inconvenience and uncomfortable feeling. It was an important advantage in this system that remote sensing was performed by non-wearable sensors. In addition, we challenged experiments with novelty, and measured many data at the same time. Hence, this system was put to practical use, and we obtained a patent for this system.

However, it has been pointed out that this result in sensing humans was still not adequate. It is necessary to measure motions more precisely, because what were detected in this experiment were just motions. In terms of detecting going out, waking up, and going to bed, it was thought to achieve a certain level of result. However, it is requisite to measure subjects' behaviors and movements to observe heir daily life in the real sense of the term. At the same time, human motion was not always considered as measuring changes in their physical condition. In addition, this system was developed with the aim of long-term health management, which is detecting before deterioration of health. This system appears very useful for daily checking based on this standpoint. Additionally, it is thought to detect troubles in about ten minutes by comparing usual patterns which was stored in the controller unit. Furthermore, a system corresponding to emergencies, for example falling, is still being developed. It is absolutely imperative to upgrade this system for detecting the physical condition.

In our laboratory, we are continuing research and development on the system to detect biological signals, for example, heart rate, sphygmus, and body temperature by remote sensing. By translating this system into practical applications, there is a possibility that it would appear that early symptoms in disorders can be detected by remote sensing. Thus, system managers and the elderly themselves can prescribe measures. Currently, we are working practical trial into operation, and lead to the final step in this trial.

5 Conclusion and Future Work

For the purpose of practically applying our new system for elderly people, questionnaires and two experiments were carried out. From the results of the questionnaires, we realized that the characteristic pattern was influenced by a change of the elderly' individual life environment. Therefore, it was necessary that several characteristic patterns be extracted and kept in the memory of the supervisor unit in case the environmental changed. In addition, from the experimental results, it was ascertained that this support system could measure and analyze elderly people's behaviors. According to these results, it was possible to watch closely the condition of the elderly people from a distant public institution. These results indicated that the system was useful for an elderly support. Now, some functions of this system are used in at least 20,000 houses of the elderly people in Japan, and is playing significant part in their life. Meanwhile, research on detecting elderly's physical condition by this system continues in our laboratory [11].

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Design Approach of Simulation Exercise with Use of Device and Its Significance

Design of Novel Device for Realistic Experience of Being a Hemiplegia Patient

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Abstract. This paper addresses design approach of simulation exercise with use of tool to encourage an able-bodied person to understand the situations of a patient suffering from loss of perceptual function and motor function due to brain damage from perspective of human-human communication enhancement. The author considers that a traditional hemiplegia simulation suit provides an experience different from actual experience that a patient has, and has focused on the variance between bodily actions in thinking and feeling and bodily actions in physical situation in order to generate much more realistic experience of being a patient. This paper describes two simulation devices based on this approach: a hemiplegic-gait simulation device and a strange-depth-feeling device, and also discussion of the significance of such simulation exercise and the development of user's ability to understand the situations of a patient.

Keywords: communication enhancement, simulation exercise, hemiplegia patient, illusory kinesthesia, reflex action, binocular parallax.

1 Introduction

A human assistive technology is defined as a technique that supports weaker or insufficient ability through use of technology, or a technique to make "inability" into "normal ability". Most of remote communication tools that support bodily interactions between people who are in physically separated places are intended to support "inability" of users at each place. For example, the use of videophone can support facial expression comparing to the use of telephone, and the use of robot avatar can support moving around at the remote place comparing to the use of videophone. This means only using telephone indicates "inability" of visual interaction, and using videophone indicates "inability" of physical interactions. Such "inability" of interaction between remote users has leaded to advance novel communication tools. This process is considered as a way from "inability" to "normal ability" as if they were in a face-to-face situation, and this indicates that those tools are for just "assistive" and "supportive".

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 315–324, 2013.

On the other hand, a widely-used microblog (e.g. Twitter [1]) provides a novel communication mode different from face-to-face communication. For example, another technology encourages users to nod their heads during conversations and leads to enhance the mood [2]. These communication tools can be considered as "enhancing" technology not rather than assistive technology. Generally, a human enhancing technology is defined as a technique that drives "natural ability" to "much stronger ability" through use of advanced technology, or a technique to make "normal ability" into "advanced ability". Such well-known technologies are robot suit (e.g. HAL [3]) that strengthens motor ability such as lifting up heavy load, and a widely-used smartphone that enhances cognitive ability such as storing a lot of addresses. These technologies can be of service only when the user wears and utilizes the tools, meanwhile, no functions are available when they don't utilize them.

The author considers that a concept of enhancing technology can expand by including technologies and tools for exercise and training. By use of those technologies and tools, it would be easy for users to find clues to master high skills and to develop such abilities. The significant feature of expanded concept comparing to narrow concept of enhancing technology is that such acquired ability carries on even after users utilize these technologies.

This paper refers to the ability to understand other communication partner from perspective of human-human communication enhancement based on the expanded concept. Especially the paper addresses design approach of simulation exercise with novel tool to encourage an able-bodied person to understand the situations of a hemiplegia patient. And the paper also describes the significance of such simulation exercise and the development of user's ability to understand the situations of a patient.

2 Previous Simulation Tool

The simulation exercises have been conducted in order that able-bodied people may understand the "unusual" situations of other people such as hemiplegia patient, the visually challenged, the deaf and hard-of-hearing, and the aged. In those exercises several simulation tools have been utilized to let users experience low perceptive and motor function temporarily and non-invasively. The simulation exercises with use of tools are categorized mainly into three: 1) exercise with use of existing assistive tools, 2) exercise relating to cognitive dysfunction, and 3) exercise relating to motor dysfunction.

In the first category, an able-bodied person has experiences of moving around a building and a town with use of wheel chair or of brace aged person or person with motor dysfunction utilizes.

In the second category, an aged simulation suit [4] is often utilized. An able-bodied person experiences narrowed visual field and yellowish sight by wearing the goggles that is designed for simulation of aged-related visual field defect and cataract. Then the person also has aged-related difficulty in hearing high-frequency sound by wearing earplugs. Additionally, another simulation exercise for a patient with unilateral spatial neglect, who is unaware of half in visual space, has been devised that the subject sees shifted visual space by wearing glasses embedding prism inside [5] or by viewing VR space with HMD [6].

In the third category, an aged simulation suit is utilized as well as in the second category. The able-bodied person experiences the difficulty in walking and in moving limbs by attaching weight and restraint on limbs and body for simulation of aged-related muscle weakness. Recent developed suit called "MAX" has flexibility for various aged simulation by adjusting load in different levels [7]. Another well-known tool for lower motor function is a hemiplegia simulation suit [4]. The hemiplegia simulation suit consists of jacket and physical restraint for upper and lower limbs, and the person wearing the simulation suit would experience the hemiplegic-related difficulty in moving joint.

Above-mentioned tools such as aged and hemiplegia simulation suit are often utilized for practical training in professional school for nurse and physiotherapist, and then several reports refer to advantageous effect that such exercises encourage students to understand the difficulty senior or patient faces and to consider their mental conditions [8]. On the other hand, other reports point out several problems in the simulation exercises, which include low quality of existing simulation comparing to actual experiences senior and patient have [9]. Though there are several reviews of existing simulation exercises, the essential design method for improving simulation tools has not been proposed yet.

The subsequent chapter refers to a novel design approach of simulation exercise to generate much more realistic experience being a hemiplegia patient.

3 Novel Design Approach

In Japan, there were approximately 123,000 deaths in 2010 due to brain injury such as brain bleeding and cerebral embolization. Even after escaping death, patients suffer from bothersome paralysis of perceptive, cognitive, motor function and so on. The author takes notice of hemiplegia that paralyses unilateral side of body, that is, suffers from loss of perceptual function, motor function and their coupled functions, because there are a lot of hemiplegia patients comparatively. Brain-injured patients including hemiplegia often have unusual experiences unimaginable to able-bodied people [10].

For example, some of hemiplegia patients often lament over as follows; "I don't understand how to move my leg and arm.", "My leg extends automatically against my will.", "The more I try to move my leg, the more the my leg doesn't move." , and so on. The specific feature of such patient's experiences is not only that there are perceptive, cognitive, and motor dysfunctions, but also that the patient is completely unaware of symptom itself of such dysfunctions. This indicates that the coordination between subjective bodily actions in thinking and feeling and physical bodily actions in real situation has metamorphosed before and after paralysis. An able-bodied person can organize dynamically the coordination according to the situation where the person faces, meanwhile, the patient has to act in the real situation with the altered coordination capability. The author considers that this point is the most significant difference between a patient's experience and an able-bodied person's one. Considering this capability, the simulation exercise with use of a traditional hemiplegia simulation suit is undoubtedly different from those actual experiences that hemiplegia patients have. This is because an able-bodied person wearing the traditional simulation suit is able to understand how much the person cannot move easily their limbs with the load, and to adjust the movements.

The author believes that working on the coordination, or especially making the variance, between subjective bodily actions and physical bodily actions leads to a novel simulation exercise to generate much more realistic experience of being a hemiplegia patient. Though any traditional simulation exercises with use of tools have not been based on such idea as far as the author has investigated till now, the author has noticed the similar phenomenon that the variance occurs between subjective bodily actions and physical bodily actions, in interactions between people who are in physically separated places. For example, during use of videophone, when a local person tries to make eye contact with remote partner, probably the local person looks to the eyes of remote partner on a display directly. Consequently, the remote partner often sees forehead of the local person, and feels embarrassment. The similar miscommunication is often observed when a local person points to a remote object on a display during use of videophone. These miscommunications often occur when a local user still believes that the local user can interact with another remote partner successfully in thinking though the local user doesn't express adequate behavior in the real situation. Especially the extremely-bothersome problem is that even if the local user knows the variance between physical interaction and video interaction, the user often exhibits such inadequate behavior naturally, and the user attributes the miscommunication to interaction itself not to the insufficient communication tool. If anything, the author puts emphasis on the significance of such variance between subjective actions and physical actions, and applies the variance to simulation exercise positively to generate much more realistic experience of being a hemiplegia patient.

Therefore, the author focuses on the coordination among various processes that are components of actions. For example, when an able-bodied person takes each step while walking, the person can, consciously or not, exploit and coordinate many varieties of processes such as touching the ground with foot, seeing toward walking direction, or adjusting standing posture. Therefore, when such relationships break down, the continuous process in walking including the coordination between subjective actions and physical actions is also influenced. The author considers that the discontinuous process is just the experience that a hemiplegia patient has in a sense. A hemiplegia patient is often unable to percept current bodily situation for taking first step. Even when the patient scarcely makes a step, the patient would confront a difficulty in taking another step because the continuous walking process cannot be achieved. The hemiplegia patient always struggles with negative progression, and the patient experiences mental conflict between intentions that the patient wants to walk and inconvenient body which doesn't move as the patient intends to.

Therefore, in order to generate much more realistic experience of being a hemiplegia patient the author considers making the variance between subjective bodily actions and physical bodily actions by manipulating purposefully such smooth coordination among various processes. The next chapter describes specific design of two simulation devices based on this approach by focusing on movements of legs in motor function and depth feeling in perceptive function.

4 Design of Simulation Devices

4.1 Hemiplegic-Gait Simulation Device

The author's group has researched to design and develop a hemiplegic-gait simulation device [11]. This section describes how to apply the approach mentioned in previous chapter to design of the simulation device. The essential idea is making difference between “posture and physical movement of actual lower limb” and those of “perceived lower limb”. To do so, the author has focused on four phenomena influencing posture and movement: 1) illusory kinesthesia, 2) reflex action, 3) preventing adaptation to stimulation, and 4) providing fluctuating load around threshold.

Firstly, an illusory kinesthesia, phenomenon that a subject feels as if its limb were moving even when the limb is still, is applied to make a difference between physical movement of left leg and one of perceived left leg. The motor illusion is generated based on tendon vibration method by providing appropriate vibratory stimulation onto specific tendons [12]. Secondly, a reflex action is applied to let the left leg automatically move independently from a user's intention. This could be achieved from the same technique as generating the motor illusion. Thirdly, intensity and its timing of a vibratory stimulation for motor illusion and reflex are controlled by an experimenter for a user not to adapt to the stimulation. Lastly, a user’s knee and ankle are moved subtly around threshold that a user scarcely perceives, in order to make more difference between posture of physical left leg and one of perceived left leg. Additionally this manipulation can also change intensity of motor illusion.

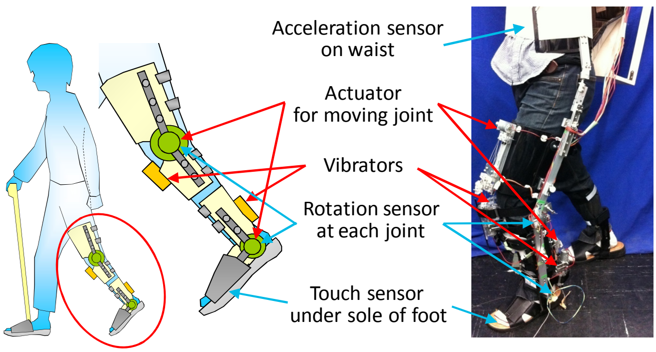
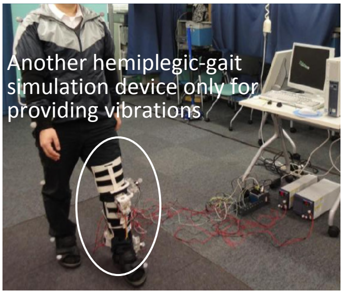


Fig. 1. A hemiplegic-gait simulation device

By integrating these four phenomena and by adjusting each degree of influence, the author supposes that the hemiplegic-gait simulation device will generate much more realistic experience than existing simulation suit does. Fig. 1 illustrates the hemiplegic-gait simulation device. The vibrators for generating motor illusion and reflex, and actuators for adjusting the degree of motor illusion by moving the limb and for providing subtle load are attached on left knee and ankle. Several sensors are installed around both joints and soles of both feet for measuring posture and gait cycle, and for adjusting load. Several subjects have experienced walking with wearing the simulation device under various experimental conditions. Fig. 2 shows a scene of experiment and an example of maximum flexion angle of knee joint in swing phase when a subject walked in a condition of only providing vibratory stimulation on knee joint. Such preliminary results indicated that able-bodied subjects experienced tonic extension of left leg that is similar to hemiplegia patients often experience.



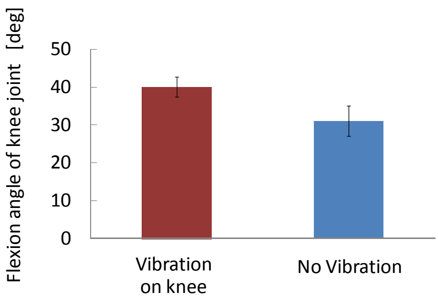


Fig. 2. A scene of experiment and maximum flexion angle of knee joint in swing phase

4.2 Strange-Depth-Feeling Simulation Device

When people reach out to take an object and get around an obstacle, depth perception is one of important functions to perform such actions. It is reported that it is influenced for some of hemiplegia patients to reach toward an object by changing of such depth perception [13]. The author has focused on such functions of depth perception and on design approach of making the variance between the depth feeling that the user is just having experience of and the depth feeling that the user has experienced ever. And the author supposes that such variance will lead to unusual physical actions different from subjective actions, as it is reported that when a subject sees an illusional figure, there is a difference between the length the subject feels and the length the subject indicates by shaping a hand [14]. Based on such approach the author's group has devised a strange-depth-feeling simulation device that strengthens and/or reverses the depth feeling for realistic experience of being a patient with damaged depth perception [15].

The author has given emphasis to let the user see objects without decreasing quality of visual image such as fineness, size of and viewpoint on the objects. Therefore, the author has adopted that the device is composed of mirrors and prisms that just change light path and the device never embeds video camera. To do so, the author's group has taken notice on Hyper Scope for strengthening the depth feeling and Pseudo Scope for reversing the depth feeling [16]. Those tools are designed based on the mechanism which adjusts binocular parallax by putting slightly-shifted visual images into each eye as applied to three-dimensional television. Considering mechanisms of these two scopes, the author's group has devised a basic structure that increases and/or reverses binocular parallax purposefully by moving positions of mirrors and right-angle prisms inside as illustrated in Fig. 3.

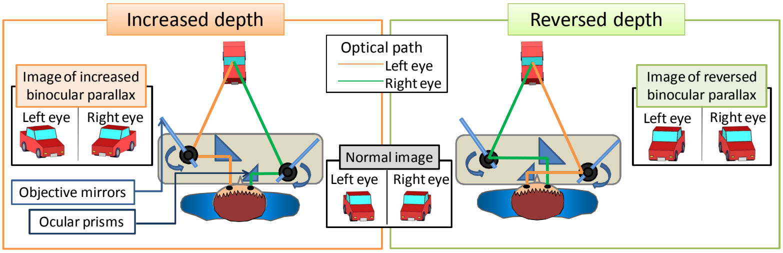


Fig. 3. A concept of a strange-depth-feeling simulation device

Especially the device requires three functions: 1) autofocus, 2) automatic adjustment of binocular parallax, and 3) switching between increasing and reversing mode, in order that visual image keeps on being focused even when the distance between the device and the object has changed and that various depth feeling can be generated without manual manipulations.

Therefore, the simulation device has been constructed that is composed of two mechanisms as illustrated in Fig. 4. The mirror rotation-slide mechanism is for adjusting focus and for adjusting binocular parallax, and embeds stepping motor and laser sensor, which measures the distance between the device and the object ahead of the device. Then the prism switching mechanism is for switching the mode and for adjusting to various interpupillary distances, and embeds two ocular prisms which are slid and stopped manually. And a host computer controls rotations and positions of each mirror by using distance data from laser sensor.

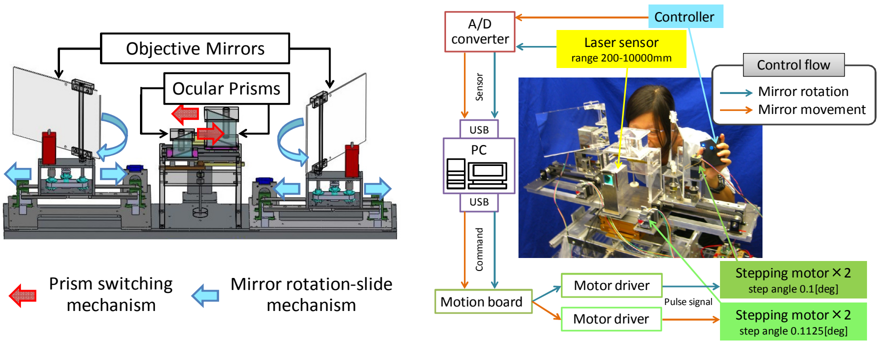


Fig. 4. Mechanism and schematic diagram of a strange-depth-feeling simulation device

At this time several subjects experienced strange depth feeling with use of the device and they reported their impressions when they saw a small statue that rises to its full height with extending front arms forward as follows; in increasing parallax mode, some of them reported that they felt the degree of extension of the arms seemed to be bigger and as if the arms were coming to them. Then in reversing mode, some reported that they felt the arm bended in the reverse direction, and some of them reported that whole arms were located backward.

The author will have further experimentation whether this device lets users have unusual experiences in reaching out and walking around as a patient has.

5 Discussion

The author considers the significance of simulation exercise and the development of user's ability to understand the situations of a patient through the simulation exercise.

When an able-bodied person walked with the hemiplegic-gait simulation device, a peculiar circumduction gait was observed occasionally. The circumduction gait indicates that the person moves its leg as throwing it frontward from the outside at hip joint as a pivot point, and is considered as a compensatory movement that movable body parts move instead of other non-movable body parts. Such compensatory circumduction gait is often observed in hemiplegic gait as well. In a sense the author thinks the simulation device achieves to let an able-bodied person have some of experiences of being a hemiplegia patient because such observed circumduction gait is in common with hemiplegic gait. However, the circumduction gait in hemiplegia patient can be generated barely based on limited perceptive and motor abilities. In contrast, the able-bodied person's circumduction gait emerges as one of various choices based on rich potential. Therefore, even if an able-bodied person moves with a circumduction gait by wearing the device and faces the situation where a hemiplegia patient might stop moving, the person will keep on moving robustly by changing a gait and by using other body parts such as swinging arms and twisting upper body.

The author considers that such high adaptability is one of the most different ability comparing to hemiplegia patient's ability. This indicates that the goal of a simulation device is not that an able-bodied person has simply experience of a movement similar to hemiplegic gait. Moreover, it is significant not only that an able-bodied person is aware of definite difference in adaptability between of an able-bodied person and of a hemiplegia patient, but also that the able-bodied person is able to develop the ability to be aware of such difference in adaptability. That is to say, the important thing that should be done is to design such an effective simulation exercise which lets a user find clues to understand how much the patient adapts to the real situation, and which lets the user improve its ability to discriminate the possibility of actions in each patient. Such development of the user's ability to ascertain the possibility of a patient’s actions requires a high motor skill primarily, as it is reported that a high-skilled person is able to have high sensitivity in observing a movement related to the skill [17]. Then the high skill in the simulation exercise means that the able-bodied user is able to imitate naturally a movement similar to a patient's movement even without use of the device. On the surface the imitations might seem to be very easy, however, in fact it is difficult for the user to perform the imitations because such imitations are new movements that the user has never experienced and can be achieved by reorganizing the movements. The difficulty is essentially the same as in performing skilled movements in sports and dances from a standpoint of reorganizing the movements.

The author supposes that the advanced simulation device will provide a user useful clues and let the user to reorganize the movements similar to a patient's movements. It is the research topic in the next stage to design such a simulation device, and to do so, the author focuses on a program for developing the ability, which has been devised for treatment of developmental disorder in neurocognitive therapy. The program consists of utilizing the difference in actions, coordinating the difference and the image of actions, and expanding selectivity of actions [18, 19]

Then, as far as the author has investigated the coursework including simulation exercise with use of simulation suit, for example, in a school of nursing [8], the coursework is intended to let students study to understand inconvenient situations in daily life and mental load that a patient feels, and way of assistance for the patient. And in order to lead to more effective exercises, it is also reported that the exercises require sufficient time to experience, include role-plays about simulated patient, helper and adviser, and let students have images of being a patient and a helper. In light of these considerations, the author expects that an advanced simulation device will contribute to such imagination finally. Imitating bodily actions of a patient can be achieved through reorganizing the movements, and such process will lead to acquire ability of imagination to patient's actions. It is the author's final goal to design such simulation exercises with advanced device as human enhancing technology.

6 Conclusion

The paper addresses design approach of simulation exercise with use of tool to encourage an able-bodied person to understand the situations of a hemiplegia patient.

Firstly, the author considered miscommunications observed in interactions between people located in physically-separated places and unusual experiences hemiplegia patients have in the real situation, and focused on common specific feature of the variance between subjective bodily actions and physical bodily actions. Then, the author devised the approach of manipulating the variance purposefully in order to generate much more realistic experience of being a hemiplegia patient. Subsequently, the author devised two simulation devices: a hemiplegic-gait simulation device that generates illusory kinesthesia and reflex action, and a strange-depth-feeling simulation device that increases and/or reverses binocular parallax. A few preliminary results indicate that the simulation device may be suitable for letting an able-bodied person to have realistic experience of being a patient. However, as these are small-scale pilot studies, further experimentation is required to validate these observations.

Finally, the author considers the significance of simulation exercise with use of tool that the exercise encourages a user to understand the difference in adaptability of bodily actions, or to improve the user's ability to discriminate the possibility of actions in each patient. Through such studies, the author will design the simulation exercises for user to acquire the ability of imaging being a patient.

Acknowledgements. This work is supported partially by JSPS KAKENHI Grant-in-Aid for Scientific Research (C) (23500265) and by Rohm research grant. The author would like to thank Prof. Masahiro Tamachi for his significant advice. A hemiplegic-gait simulation device is constructed by graduate students, Daichi Ojiro and Genta Kawase, and a strange-depth-feeling simulation device is constructed by graduate students, Yutaro Yamada and Tomotaka Horiuchi.

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Acceptance of Telemedical Treatments – A Medical Professional Point of View

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Abstract. The demographic change has tremendous consequences for health care availability, with a growing mismatch between rising numbers of patients and the declining number of care personnel. As a consequence, considerable shortcomings in availability, accessibility, and quality of health care can be expected. Telemedicine and telemonitoring services are promising approaches to compensate this gap, especially for long-term monitoring, nevertheless also within the supply chain of health care. Despite the potential, the acceptance of telemedicine is quite low. In this paper we report on two studies focusing on acceptance of telemedical services. First, chronically ill persons were experimentally studied with respect to their acceptance of telemedical systems. Second, a survey was conducted to assess medical professionals' points of view. Findings reveal perceived benefits in the context of telemedical services, however, also considerable barriers, especially on the medical doctors' side. Outcomes may contribute to the development of a sensitive and transparent communication and information strategy for stakeholders, as well as a public awareness for the benefits and the drawbacks of telemedical services.

Keywords: Telemedical treatment, telemonitoring, electronic services, medical professional technology acceptance, biomedical engineering.

1 Introduction

As a consequence of the increasing graying of our societies, currently a vivid discussion examines how the consequences of the demographic change can be met [1] [2] [3] [4] [5]. This discussion is quite challenging as it touches sensible and serious topics: One of the challenges regards the economic shortcomings in the health insurance systems, connected with the question of how societies can care for the increasing number of seniors which need to be medically cared. Another challenge are the shortcomings regarding the availability of caregivers and facing a considerable lack in the medical supply chain with increasingly lower number of persons that are doing the caring jobs. In addition, traditional family structures are dissolving. In contrast to former societal structures, many old people live alone and have no children, who used

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 325–334, 2013.

to take over caring for the older parents [6]. Aggravating the situation, there is an enormous discrepancy between the availability of medical doctors in rural and urban regions [7]. In rural areas, predominately senior citizens are living, who – due to their lower mobility – will have serious problems to make visits to the doctor’s office [8].

Concluding, there is an urgent need to develop new, innovative medical care concepts that are able to compensate for the bottlenecks in medical care [9][10].

1.1 Technology in the Doctors’ Office

Technology in the doctor’s office is not new. More than 20 years ago, computer systems have been installed in the majority of doc-tor’s offices, mainly in order to help accelerate organizational work. This increased the number of patients treated and was accompanied by a higher efficiency and a reduced fallibility of data handling [1][11][12]. However, patients still have to come into the doctor's office. While this may be inevitable as a physical examination is required in some cases, in other cases a personal contact is not factually necessary from a medical point of view [2]. Thus, telemedical services could be an economically and organizationally interesting alternative or addendum to the traditional visit to the doctor’s, for all persons involved [13][14]. Already in the 90s, studies considered the consequences of telemedicine for different stakeholders [9][11][12], addressing patients, providers, policy as well as societal structures.

The power of mobile technologies has improved dramatically and the possibilities are very different to earlier times [15] [16] [17]. Today, information and communication technology plays an integral part in emergency medicine [18] [19]. Additionally, mobile technology also enters private spaces and is increasingly incorporated in smart homes [20] [21]. Recently, there are research trends for more innovative technology supporting doctors [22] [23]. One example is the virtual doctor’s visit, a telemedical scenario which enables remote virtual consultation hours between doctor and patient [24]. Here patients do not need to visit doctors in person in order to get medical advice, but instead they can choose to communicate with the doctor virtually and clarify routine problems or questions prior to a face-to face consultation.

1.2 Benefits and Drawbacks of Telemedicine

Within literature there is a vivid discussion and a growing interest in potential benefits of teleconsultations in different medical fields, e.g., ophthalmology [25], rehabilitation in stroke care [26], or orthopedics [27]. However, not all views - medical, sociological, economic or psychological - are positive regarding the real benefits but reveal also critical thoughts accompanied by a very sensible discussion about the overall usefulness of telemedicine. In addition, insufficient knowledge is present as to what extent individual beliefs, (social) trust in healthcare and technology as well as perceptions of potential benefits and risks are influencing telemedicine’s acceptance [28] [29] [30]. This knowledge gap is due to the fact that traditional acceptance studies predominately concentrate on the technologies in the working context [31]. However, especially in the medical context, technology acceptance is influenced by many other factors [32] [33]. User diversity plays a prominent role: gender [34], age [35], technical upbringing and expertise [36], and cultural factors do considerably decrease technology acceptance [37]. Large impact on acceptance and the willingness to adopt medical technology also comes from the usage context: Technologies entering private spheres in the home context [20] and invasive medical technology that is close to [28] or even inside the body [32] are critical factors which are known to be fragile determinants of medical technology. Also, within the public perception, a broad reluctance prevails [21]. People are quite skeptical towards telemedicine regardless of its potential. Concerns about security and privacy are key issues [29] [21] as are fears such as doctors being afraid that a therapy mediated by technology might decrease care quality or even finally lead to their unemployment [24].

1.3 Questions Addressed

In most of the studies focusing on telemedical acceptance a quite generic view is examined. Only little is known regarding the stakeholder's view – meaning the patients and the medical doctors. This was undertaken in the present study. In a first, experimental approach, patients suffering from chronic heart disease evaluated the usability of a prototypic telemonitoring system (more details see [21]). In a second study, an exploratory survey was applied asking medical personnel about perceived benefits and drawbacks.

2 Study 1: Patients' Point of View

The first study focused the usability of prototypic telemedical application. Chronically ill persons (coronary heart disease) and healthy persons had to evaluate the perceived reliability of the data acquisition functionality. Participants had to carry out a telemedical task and then assess the usability and learnability of the prototype as well perceived privacy, trust, and data security. We assumed that patients would differ in their opinions from healthy persons due to their experience with the disease and their higher awareness for the importance of continuous monitoring.

2.1 The Lab Environment: The Future Care Lab

The lab environment used as an experimental space was the Future Care Lab at RWTH University, Germany, part of the European Network of Living Labs (ENoLL). The lab is conceptualized and technically realized as an intelligent living room, equipped with different medical assistive devices. A full-scale prototype room as a simulated home environment was built which enables to test experimental interfaces with persons of different ages and health states. Different parts of the room (walls, floor, furniture) are used as input and output modalities for medical services. The wall of the living room represents a huge multi touch display (4.8m x 2.4m) that allows to examine telemedical services in the home environment (Figure 1).

Fig. 1. Communication with the doctor (left) and telemedical systems (right) (® Kasugai)

2.2 Participants

28 persons (51% female) took part (24-85 years). 50% of the sample was chronically ill (different forms and degrees of coronary heart disease). Participants were recruited through advertisements in a local newspaper. Participants reported to have different professions and educational levels. They were not compensated for their participation.

2.3 Materials

In order to assess usability and learnability, we used the System Usability Scale (SUS, [39]). Participants had to answer ten questions (5-point Likert scale, from 1 (''strongly disagree'') to 5 (''strongly agree''). Overall, a maximum of 100 points could be reached. The following items were explored: (1) I think that I would like to use this system frequently. (2) I found the system unnecessarily complex. (3) I thought the system was easy to use. (4) I think that I would need the support of a technical person to be able to use this system. (5) I found the various functions in this system were well integrated. (6) I thought there was too much inconsistency in this system. (7) I would imagine that most people would learn to use this system very quickly. (8) I found the system very cumbersome to use. (9) I felt very confident using the system. (10) I needed to learn a lot of things before I could get started with this system.

2.4 Tasks and Procedure

First, participants were introduced to telemedicine and the possibility to have electronic applications at home, supporting persons regarding a continuous monitoring of vital data related to their disease. In a second step, the experimenter acted as a model and demonstrated participants how to interact with the system (using the scale which was implemented invisibly in the floor), as well as how to take their blood pressure. Participants then had to do the same, navigating through the system menu structure to measure their vital signs. Finally, participants filled in the usability questionnaire.

2.5 Results

The evaluations of the system usability were analyzed by univariate and multivariate analysis of variance. The level of significance was set at 5%. In Figure 2, outcomes are visualized. As can be seen, the general usability is very high. Out of a maximum score of 100 points, the mean usability score reached 91 points (SD = 12.3 points). As expected though, differences appeared between healthy and chronically ill persons ($F(1,26) = 7.7$, $p<0.05$). People suffering from heart disease perceived the usability of the system higher than healthy persons (93 respective 85 out of 100 points max).

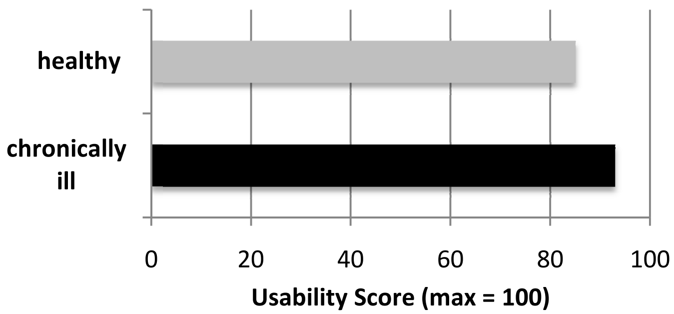

Fig. 2. Usability scores in chronically ill and healthy persons

Patients value telemedical systems more than those who are unaware of the disease-related implications. The high evaluation of the systems' usability was found to be independent of age and gender, hinting at a generic (positive) outcome. When looking at the findings regarding the perceived trust in data security and the system's reliability we also found high scores. From the 5 points to be reached as a maximum, data security received, on average, 4.1 points (SD = 0.8) and system reliability 4.3 points (SD = 0.7). Again, outcomes did not vary with gender and age of participants. Separate correlation analyses for persons suffering from chronic heart disease and healthy persons did not show significant differences regarding trust, privacy, and reliability.

Overall, it could be found that the requirements with respect to perceived trust and security are universal demands for sensitive technology environments.

3 Study 2: Medical Doctors' Point of View

This Study Focuses on Medical Care Personnel and Their Acceptance of Telemedicine.

3.1 Survey Instrument and Measures

The survey assessed general attitudes towards telemedical systems. This includes spontaneous associations with telemedicine as well as the willingness to use telemedical systems in the working environment. Then two scenarios for monitoring a cardiac patient were described: (a) the use of telemedical systems and (b) conventional treatment. Participants were instructed to take the role of the attending physician of a patient with heart disease who has to record his/her vitals daily. In the first scenario the patient is equipped with a telemedical system to automatically record his/her vitals and transfer them to the doctor. Only in case of emergency and irregularity, the patient would have to consult the doctor. The second scenario introduces the conventional way of documenting the vitals on a daily basis, noting them in a diary and consulting the physician once a month to check the data.

Participants had to evaluate 13 different criteria regarding both treatments: time efficiency, treatment quality, cost efficiency, false alarms, convenience, compliance, data analysis, data security, privacy, legal protection, emergency adequacy, long term adequacy. The criteria had been identified as most important in focus groups with medical professionals prior to the study (Mennicken et al., 2011). Finally, an overall decision for one of the two treatment options was asked for.

3.2 Participants

The sample consisted of 39 medical professionals (doctors and professional care persons) and 44 control persons (different professional background). 51% were female. The age range was from 21-72 years of age. Participants were recruited through advertisements in a newspaper (non-medical control) and in medical practices, hospitals (medical group). Participants were not compensated for participation. The level of technical self-confidence was about the same within the two groups (doctors: M=70.3/100 points max, SD=15.6; control group: M=72.2/100 points max, SD=13.7).

3.3 Results

Here, the evaluation of the different criteria in the telemedical compared to conventional treatment is reported for both groups (medical professionals vs. control group). In Figure 3, the results are presented. Bars on the left hand side represent preferences of the conventional treatment, bars on the right hand side depict preferences of the telemedical treatment in both groups. What can be seen there is that the telemedical approach is regarded as more advantageous than the conventional treatment regarding data analysis, long term adequacy, emergency adequacy, and treatment quality, but is also perceived as more susceptible to false alarms. Problems are seen – therefore favoring the conventional approach – within cost efficiency, data security, privacy protection, and time efficiency. Nevertheless, participants of both groups report an overall preference of the telemedical approach, basically ascribing a high usefulness of telemedicine as addendum to the face-to face consultation hour.

Even though both groups show the same preference and non-preference patterns, it is obvious that the medical professionals are much more reluctant and show a higher aloofness towards the telemedical treatment. Throughout, medical professionals' votes are less positive and more negative in comparison to the non-medical group. Beyond usability and privacy concerns, which were reported by all, medical personnel specifically complained about missing technical competence that was not trained during education. They feared not being able to meet the requirements when using novel technology in combination with the responsibility for a safe patient care.

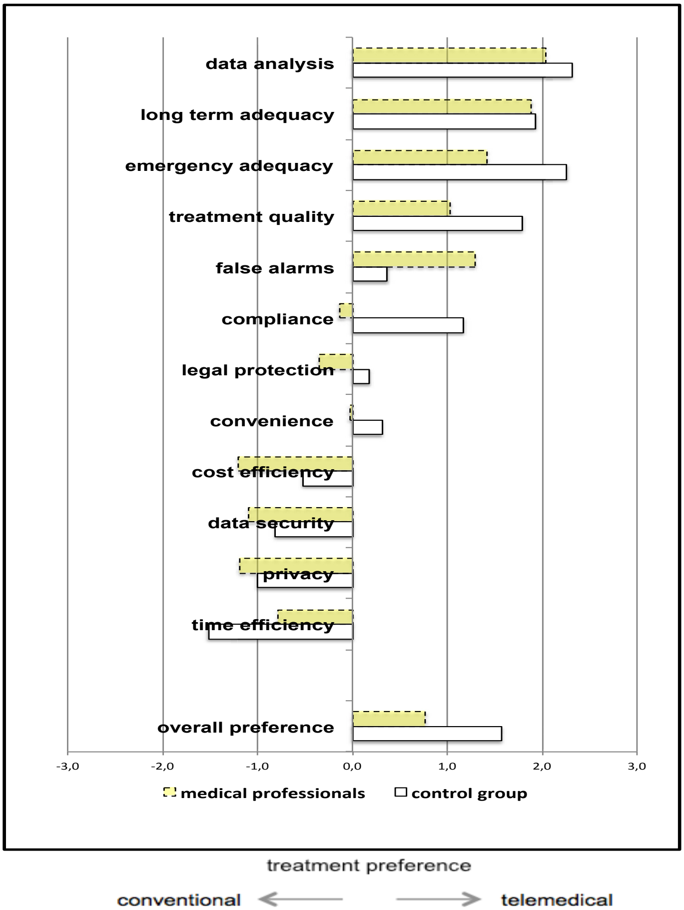

Fig. 3. Preference ratings of the telemedical vs. conventional treatments in both groups (medical professional colored bars vs. non-medical control persons)

4 Discussion and Conclusion

Overall, the two studies focusing on the acceptance of telemedicine for patients (Study 1) and medical care personnel (Study 2) revealed interesting insights. The findings provide support for our hypothesis that patients – as experts for their disease – show a higher acceptance for telemedicine and the usability of the telemedical approach, in contrast to healthy persons who, however, also ascribe a high usability to the system. Medical personnel – including both doctors and care personnel – are much more reluctant and address different aspects which need to be considered. While there is a positive attitude toward the perceived adequacy of the telemedical approach, especially for emergency situations, and also toward the accuracy and quality of the data required for monitoring vital parameters, the perceived drawbacks include not only the higher probability of false alarms, but also data security and privacy issues that are reported to be more problematic in telemedical treatments. Doctors' barriers are low usability of technical devices, assumed difficulties in handling the devices, and low technical competence which might be the reason for their view that telemedicine is more time-consuming in contrast to the conventional approach.

Overall, the findings show that medical professionals should be especially included into the development of future telemedical systems. Not only because they do have the most critical perspective, but also because their professional view could represent a highly useful information source with respect to three information and communication duties. Medical professionals' views could reveal (1) to technical designers what should be considered regarding the usability of the devices, (2) what should be discussed in the public communication policy and (3) what should be integrated in future education programs of medical professionals.

Acknowledgements. Thanks to participants for their openness to support our research. Thanks also to Kai Kasugai and Felix Heidrich for valuable technical support in the Future Care Lab.

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Part III
Mobile Interaction

NFC Provided User Friendliness for Technologically Advanced Services

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Abstract. This paper will discuss how an NFC enabled university campus can provide a wide range of user-friendly advanced services for its students and staff. These services combine information sources related to teaching, room reservation, social networking, proximity sensing, information collection and exchange, calendar services, event notifications, ticketing, loyalty cards, payment and more. In the ongoing NFC City Campus trial the usage of NFC enabled mobile phones, SIM cards as secure elements, and an adaptive infrastructure supporting information integration, demonstrates how NFC can contribute to the development of user friendly advanced services.

1 Introduction

Near Field Communication (NFC) [17] differs from other existing communication technologies in a few but important manners. Most importantly is its short range. This limitation is intentional and it contributes to security and the accuracy of proximity sensing. NFC is also intuitive to use. NFC communication is initiated with a simple touch, and can enable the usage of other technologies. An example is the usage of NFC to setup a secure WiFi connection on your mobile phone by simply touching an NFC tag. NFC has also built-in capabilities to support security [10,4]. The encryption support in NFC can be used to set up a secure channel for the NFC communication [8].

These characteristics make NFC a promising technology to combine technological advanced services with user friendliness. A wide range of advanced services is traditionally considered inaccessible for people without a lot of knowledge or interest in such technology. Such services are slowly adapted outside the group of technological savvy people. The consequence is that it is difficult to find motivation in an organization to invest resources and time in developing, maintaining and further enhancing these services. And if the services are not developed, maintained and further enhanced, the quality and usefulness of the services will degrade. User friendliness for a large number of different users with different background and technological expertise can be a major success factor when introducing technological advanced services.

Why is it NFC can play a role in user-friendly advanced services? The common NFC enabled personal device is the mobile phone with a user that can be

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 337–346, 2013.

identified. The presence of the mobile phone indicates the presence of the user. A set of possible context related data that is implicitly or explicitly given by an NFC enabled device could be linked to the user. This can be used to reason about the user's intention, current interest, relevance of data, and so on. An example could be a user planning a trip on a bus stop. When the user uses the NFC enabled mobile phone to select the destination for the bus trip on a map (that is an NFC enabled smart-poster), both the current location and the selected destination are implicitly provided as context data to the travel-planning application on the phone. The application uses the context data to present the user with information about the next bus to the selected destination and, if necessary, where and when to change bus.

The paper will give examples of a number of advanced services and describe how NFC is used to enable user-friendly service interaction. The paper builds on experiences and preliminary results from an ongoing field trial where students at a university campus are exposed to a variety of NFC enabled services.

2 Background

2.1 NFC Technology

NFC Forum [12] has defined three different NFC operation modes; Card Emulation, Reader/Writer and Peer-to-Peer [17]. In card emulation mode, the NFC device acts as (and eliminates the needs for) a physical object, such as a credit card, key, ticket or coupon. In reader/writer mode, NFC devices can read and write data from/to NFC tags, while in peer-to-peer mode, data can be transferred between two NFC devices. All three operation modes have the potential of enabling user-friendly service interaction, and can make people's lives easier and more convenient by enabling more intuitive access to new media and content services. It can for example be easier to pay; easier to discover, synchronize and share information; and easier to use transport and other public services.

NFC always involves an initiator and a target; the initiator actively generates an RF field that can power a passive target. This enables NFC targets to take very simple form factors such as tags, stickers, key fobs, or cards that do not require batteries. NFC peer-to-peer communication, where both devices are powered, is also possible. However, the limited bandwidth makes it inferior to Bluetooth for big data transfers.

NFC tags contain data, and may be configured to be both read-only and rewritable. They can be custom-encoded by their manufacturers or use the specifications provided by the NFC Forum, including the tag format for the tag header and the data format for the payload. The NFC Data Exchange Format (NDEF) specification [13] defines a message encapsulation format to exchange information (payload) between NFC Forum Devices and NFC Forum Tags [15]. Each payload is described by a type, a length, and an optional identifier. The type identifiers may be URIs, MIME media types, or NFC-specific types.

The type identifier can be used by NFC enabled devices to perform the correct action when an NFC tag is touched. On an Android phone the correct application matching the MIME media type of the tag can be opened to process the information on the tag. You can configure Android to open a given application based on this type information. This means that when you use the phone to touch a tag you do not have to open any application before you do that. Touch the tag and the correct application is opened automatically. This makes the usage of NFC more user friendly than for instance QR codes where you first have to open the QR code reading application, and then be forwarded to the correct application to process the information.

NFC technology becomes even more exciting when it interacts with the UICC (SIM card) on a phone. The UICC can act as a tamper-resistant secure element, securely hosting applications and their confidential data. The Single Wire Protocol (SWP) [6] enables direct communication between the UICC and the NFC chip on a phone. Applications on the UICC can then directly interact over NFC without involving any part of the Android system (even when the phone is turned off). This is important for applications like NFC locks and ticketing.

2.2 User Friendliness and NFC

The term "user-friendly" can be defined as "easy to learn, use, understand, or deal with"[1]. Closely related to user-friendliness is the term "usability" that in the ISO 9241 standard is defined as: "The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use". In [18] the definition of usability is elaborated on, focusing on the terms "effective", "efficient", "engaging", "error tolerant" and "easy to learn".

Papers describing NFC communication and services, such as [16] and [14], point out the user-friendliness of the technology, and claim it to be easy to use and familiar to people since users do not need any knowledge about the technology. All a user has to do is to start communication by bringing two devices together [16].

Usability of touch interaction has been studied in [19,7,11]. According to [19], the user interface of an NFC application is mainly the tag, and the work of [19,7] investigated how people locate an NFC tag, and emphasize the need for a common visual language for locating NFC services. [19] also studied the simple usage pattern of touching a tag, and users' understanding of the actions triggered by the touch.

The work of [11] evaluated and compared interaction methods; pointing, scanning, touching and text search, in a user study regarding efficiency, utility and usability. They found that touching and scanning was evaluated as the fastest method, and also ranked first in user satisfaction.

A field trial where users used NFC enabled mobile phones to access mobile Internet content is reported in [9]. The findings indicate that the users found the touch-based mobile content access easy to use, but details such as placement of tags and static/dynamic nature of content, had an impact on the user

[1] `http://www.merriam-webster.com/`

behavior and perceived quality. Based on the findings, a set of design principles for developing NFC applications was suggested.

[3] focuses on spontaneous interaction of devices, and presents a categorization of factors that influence the usability of device association. The authors aim to provide a framework that informs on the considerations needed when designing or adopting an association technique.

In our work, we have studied user-friendliness from the perspective of how NFC technology can simplify communication setup and service initiation by providing efficient, automatic startup. We compare the touch with the alternative, which very often is a manual setup of communication or startup of services.

3 NFC Characteristics Supporting User-Friendliness

We find that the characteristics of the NFC technology that in particular contribute to user friendliness (through efficient and easy to learn startup of services and communication setup, effective information collection and in many cases engaging use of technology), are the close range communication and context awareness.

Through close range communication, services and resources are uniquely determined through a simple touch. A communication and/or service is started by touching an NFC tag with a mobile device. The tag is linked to a resource or a service, and the touch is handled as a specific request for the resource/service. There is little room for ambiguity, and more startup interaction from the user is normally not needed.

The touch of a tag can for instance display information about a point of interest, provide timetables or similar, while a touch of two NFC-enabled devices can setup a Bluetooth communication between them. In these cases, the user avoids manual setup of communication where several parameters must be known and explicitly provided by the user. The user is also relieved of the burden of knowing where information is located and explicitly requesting the information.

Many applications using NFC technology have been developed [16]. In its most basic usage, data is collected from an NFC tag and displayed on the screen of the mobile device, while in more advanced applications the receiving of information triggers additional processing or delivery of user provided information [16]. Examples of the latter include applications for electronic voting or ordering of goods.

Context-awareness is supported through the physical location of NFC tags, identification of touch time, the action or selection performed by the user when touching a tag, and the mobile device as a personal belonging. When the user is touching a tag, the time of touch and location of the user is explicitly determined, and time- and/or location-dependent services/information can be presented. Also, the NFC-enabled mobile device is in most cases a personal device containing personal information (for instance preferences, interests, health information, and more) that allow for delivery of personalized information/services. The context information allows for a whole range of advanced applications where the user, through a simple touch, can obtain services/information tailored to his/her specific needs or preferences.

4 Experiments

In the NFC City project we have experimented with a wide range of NFC enabled services and applications [1,2]. In the NFC City Campus trail many of these services and applications have been deployed and made available to a group of students. The participating students are given an NFC enabled Android phone, a set of programmable NFC tags, an UICC (SIM card) with pre-installed applications, and support [5]. The provided NFC enabled phones also support the Single Wire Protocol (SWP) [6].

Below we will explore some of the services and applications developed and deployed in the NFC City Campus trail. We will discuss how NFC technology contributes to the user-friendliness of these services and applications.

4.1 Training Guidance

At two student fitness centers we have created a full size smart-poster with the different muscle groups. When exercising, the user can select a muscle group by touching that part of the poster. On the NFC enabled phone a web page describing training tips for this muscle group is opened. The web page also includes training videos demonstrating some possible exercises. At the different exercise equipments NFC tags can be touched to display videos demonstrating how they are used.

This is a very convenient way of presenting instructions as combinations of media types, and at the same time allow users to choose instructions of specific interest and bring all the instructions with them for use also at home. Alternatives include traditional posters and/or pamphlets, which can not support the combination of media types, and larger screens that may display videos, but are not so easily personalized to the specific needs of a user and are certainly not mobile. Using a mobile device without NFC, requires the user to start the an application (browser or other) and actively locate or search for the instructions. This requires explicit knowledge of where the different instructions are to be found.

Fig. 1. Student using smart-poster at fitness center

4.2 Location Check-In

On campus the entrance of key locations, like cafés, lecture halls and meeting points, are tagged with NFC tags used to check-in to these locations. Friends can then know that a given person just arrived and currently is at this location. Students use this to meet for coffee breaks without any cumbersome interaction by phone, email or SMS. By touching the NFC tag at the campus coffee bar your friends can discover that you currently are there. The service is based on Foursquare[2] and the NFC tags representing the location have an URL representing the check-in at this location.

Using NFC instead of other means of achieving this is a much simpler process for the user. No application has to be started and no web page has to be opened. The user just takes the phone and touches the tag. However, we expect some preparation from the user. The user has to be registered at Foursquare and provide some additional information. Once this is done the usage is straight forward. Touch a tag and you have checked in at the given location.

4.3 Coffee Card

The coffee card application is a combination of a prepaid service and loyalty card. Students can buy 11 cups of coffee for the price of 8 and the prepaid coffee cups are stored on the UICC. Since the UICC is a secure element, the users cannot alter its content. Each time a coffee is bought, the student touch the NFC reader connected to a tablet computer. The application on the tablet computer informs the barista that the user have prepaid for the coffee and it withdraw a single cup from the stored coffee cups on the UICC. The user can fill up the registered prepaid coffee with 11 more coffee cups using an accompanying Android application on the phone. The application will withdraw the given amount from the users bank account and then transfer the 11 coffee cups to the UICC.

Fig. 2. The coffee card Android application

The application combines in a single touch, paying for the coffee with use of the loyalty card. The user gets the benefit of the loyalty card without the hassle of taking care of (possibly a number of) paper cards. The single touch makes paying for the coffee very simple and fast. This is also the case for filling up the coffee card, which is also done through a single touch.

4.4 Ticketing

Public transportation is the recommended way of transportation to our local campus. The available public transportation is bus and to travel with the bus

[2] https://foursquare.com/

you need a bus card that you use when entering the bus. By touching the ticket machine with the bus card the tickets on the card is checked. A single card can have different tickets on it, and if a valid ticket for this ride is found, the trip is registered and the passenger is allowed to enter the bus.

In the NFC City Campus trail we have replaced the bus card with an Java Card application running on the UICC. This application emulates the bus card (NFC card emulation). Accompanying this Java Card application is an Android application where the user can see the current tickets on the bus card and buy new tickets. New tickets can then be transferred to the emulated bus card on the UICC or to another bus card using NFC. This makes it possible for you to buy tickets for family or friends that do not have an NFC-enabled phone. They can get the tickets transferred from your phone to the traditional plastic bus card. This application both replaces the bus card, and provide a very convenient way of buying tickets through the mobile phone.

4.5 The Presenter Application

The presenter application is meant for all situations where a presentation is to be presented on a screen. An Android application on the phone lists all your presentations available. If the presentation has meta-data related to when or where this presentation is planned, the application can list them in the order of relevance. Presentations planned close to the current location and/or time will be listed first. When ready to do the presentation, the correct presentation is selected and an NFC tag at or close to the screen is touched. The presentation will automatically appear on the screen and the user can use the Android application to control the presentation. This ensures no more hassle with connection cables to the projector or transferring the presentation from the USB memory stick to the computer at the lecture hall or meeting room.

The NFC tag touched contains an URL representing the screen in the room. The Android application uses this URL to connect to a web-service controlling the screen. It transfers the presentation to the server and uses a web-service API to control the presentation.

Other participants at the lecture or meeting can touch the same tag to download a copy of the presentation to their phones. In the current implementation the presentation will be downloaded to a pre-defined Dropbox folder of the user, but the application can be easily extended to download it to a wide range of storage services or locally on the phone. In the current implementation the presenter also use a pre-defined Dropbox folder as the means of transferring the presentations to the phone.

4.6 User Programable Tags

Each user are given a set of programable NFC tags and a short introduction of how to program them (using a pre-installed Android application on the phone). These tags can be used to access often used services on the phone just with a touch. This is some examples of tasks performed by the phone when touching a tag programmed by the user:

– Send a predefined SMS message to a predefined phone number. Some users have installed such a tag in the car with the message "On my way home" sent to a family member. Then they can send this message just by touching the tag (no typing of text message and no searching for mobile phone number of the receiver).
– Set the alarm clock to a predefined time. Some users have installed a set of such tags beside their beds with different wake up times. When they go to bed they do not have to open the alarm clock application and set the time on their phone. They just touch the tag corresponding to the time they want to wake up the next day.
– Put the phone in silent mode. Such a tag is typically installed at a meeting room where the user does not have to open the setting application to perform this task. It can also be a reminder for the attendants to do this at the meeting.
– Connect the phone to a wireless network. The process of setting up and typing all the configuration data to connect your phone to a wireless network can be cumbersome and error-prone. Just by touching a tag to do this is the user friendly alternative. That means that access to the tag is equal to access to the network.

The information necessary for the phone to perform these tasks are found on the NFC tags, and are examples of tasks where the touch of a tag triggers some processing on the phone.

5 Conclusion

We have in this paper described how NFC technology can support user-friendly service interaction, and have in particular identified close range communication and context awareness as important NFC characteristics for providing convenience and user-friendliness for technologically advanced services.

NFC technology can simplify communication and service startup by providing efficient and user-friendly startup through just a touch of a tag. The paper give examples of a number of NFC-enabled services, developed as part of an NFC City project and currently part of an NFC City Campus trial. There we compare the touch with the alternative, which very often is a manual setup of communication or startup of services, requiring both technical skills and knowledge of how and where to find the required information or services.

Acknowledgement. The authors appreciate support from The Research Council of Norway, through VERDIKT project 201377/S10, the NFC City project.

These experiments would have been impossible without support from our project partners in the NFC City project, and from the technical staff at the Department of Computer Science at University of Tromsø.

Finally we have to thank the five students contributing to the implementation of the NFC City applications and toolset: Martin Ernstsen, Erik Krane Langhaug, Alexander Svendsen, Simon Nistad, and Jan-Ove Karlberg.

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BARMOTIN- A Voice Controlled Mobile Tourism Information Network for Barbados

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Abstract. Throughout the world, mobile devices have become one of the standard means of communication and data access. With the rapid and continual improvement in technology, these devices have taken on several of the roles that were once restricted to laptops and desktop computers. One of the fastest growing areas for mobile devices is that of GPS navigation. Work in this area has produced a variety of navigation and information apps using GPS satellites. These apps have become very popular in developed countries and as a result, visitors to developing countries generally expect to gain access to some form of information system however basic. This paper presents BARMOTIN a voice controlled mobile tourism information system for the Caribbean island of Barbados.

Keywords: Mobile, tourism, networks, heritage, android, GPS, navigation.

1 Introduction

Barbados is the most easterly island in the Caribbean. Tourism is its main foreign exchange earner and after the civil service, is the second highest employer. Since tourism is the primary foreign exchange earner, the use of technology is seen as an essential mechanism for improving the visitor experience and encouraging multiple visits in the future. BARMOTIN provides the fundamental features expected of a tourism oriented app, such as directions to selected locations. However, it also provides information on the places of interest the user is currently visiting, since some of the places are unmanned or unknown and the visitor may only obtain very limited information about its history or culture. Another function of the system is to show locations and amenities which are in close proximity to the user's current location. For example, the user can select the nearest church in their denomination or the nearest doctor with a specific specialty.

The system provides an alerting system for the user in case of emergency. This allows operations control to send the relevant assistance to the user even if the user does not know which part of the island they are located. The user can also open an Instant Message session with operations control for any queries. The system also provides a

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 347–354, 2013.

visual and audio dictionary of the local vernacular. This dictionary will assist the visitors when they have to interact with the local population.

2 Contextual Aware Systems

The word *context* may be defined as the conditions under which an entity exists and which may influence and or change the state of the entity. For example, a context aware system may change and adapt to the location of the user (Schilit, Adams, Want, 1994).

Context aware mobile systems depend on the location of users and the surrounding cellular networking infrastructure for them to work efficiently. They also rely on information about the user and his or her environment so that the system can come up with the best ways to serve the needs of the user (Cohen et al, 2004).

There are two types of context awareness; active and passive. With active context awareness the application immediately and automatically changes its behavior to reflect the newly discovered context. When the context changes, the user no longer has access to the previous behavior as the current one takes it place. With passive context awareness the application also changes and adapts. It presents the new data to the user and if they are interested they can access it immediately or the context can be made to persist, for the user, for access to the data at a later date (Chen and Kotz, 2000). The BARMOTIN system employs both methods in its user interface.

3 Existing Systems for Barbados

Currently there are a small number of mobile apps that can be used by visitors and locals to navigate and find various sites and businesses within Barbados.

3.1 iBarbados - Destination Guide

This app presents articles on dining, beaches, spa experiences and more. It has an integrated business directory with video promotions on these businesses and tap-to-call functionality. The app also has a reward points system for the users. With this app, the user is able to browse through branded merchandise, books and music. The app also has a search engine which the user can use to select the type of places they would like to stay while on the island. It also keeps the user connected to essential services (iBarbados, 2011).

The first notable difference is that this app has static content and has to be updated periodically while in the case of BARMOTIN, the data is added in real time. BARMOTIN's main focus is on the information the user receives when they visit a site and not on the commercial aspects of these sites. BARMOTIN is useful to the local population as they can learn the history and culture associated with sites in Barbados.

3.2 iLandGuide

This app provides the usual tourism information such as local habitats, transportation schedules and food. This app comes with a detailed map which shows your current position, your destination and the best way to get there. The map also provides places of interest and upcoming events like festivals and parties so that the user can plan for them. The app conserves roaming changes by storing all of the data on the device. The user can update the data when they have a WIFI connection. It also has a search engine which the user can use to filter places they would like to visit while on the island. Users are presented with shopping deals and coupons to be used while in the island (iLandGuide, 2011).

BARMOTIN has similar map functionality but includes features that cater to the user's health and religion by adding doctors and churches by denomination. BARMOTIN further enhances the user experience by providing emergency assistance in the event the user has an accident, falls ill, experiences vehicle trouble or requires the police.

3.3 BajanNav

BajanNav is an audio navigation app for the island of Barbados. It comes with a map that shows roads, towns and villages. It displays tourist attractions, gas stations, hotels, restaurants and other business. It is funded by companies who pay to have their business placed on the map. The app took over five years to develop and has a very accurate map, which shows over 10,000 roads, each of which were painstakingly plotted. The map is very interactive and the app can issue voice instructions. The app allows users to post data about traffic condition so that other users can be warned not to take a particular route. The app also has the facility to track users with their permission (BajanNav, 2012).

The BARMOTIN navigation features are not as advanced as those contained within this app but this is not its main focus. BARMOTIN's main focus is to provide information about local services and obtaining emergency assistance. BajanNav is updated every six months which means that the users are only able to see new additions twice a year but with BARMOTIN, updates are immediately available.

4 The BARMOTIN System

Figure 1 shows the overall architecture of the BARMOTIS system. It is essentially a network of mobile devices, cloud servers and legacy systems. It consists of 7 components and is based on Microsoft Windows, Java and Unix technologies.

4.1 The Information App

Conventional tourism marketing apps concentrate on the sites and activities that are current and are commercial in nature. Most of the tourists who visit a country not only

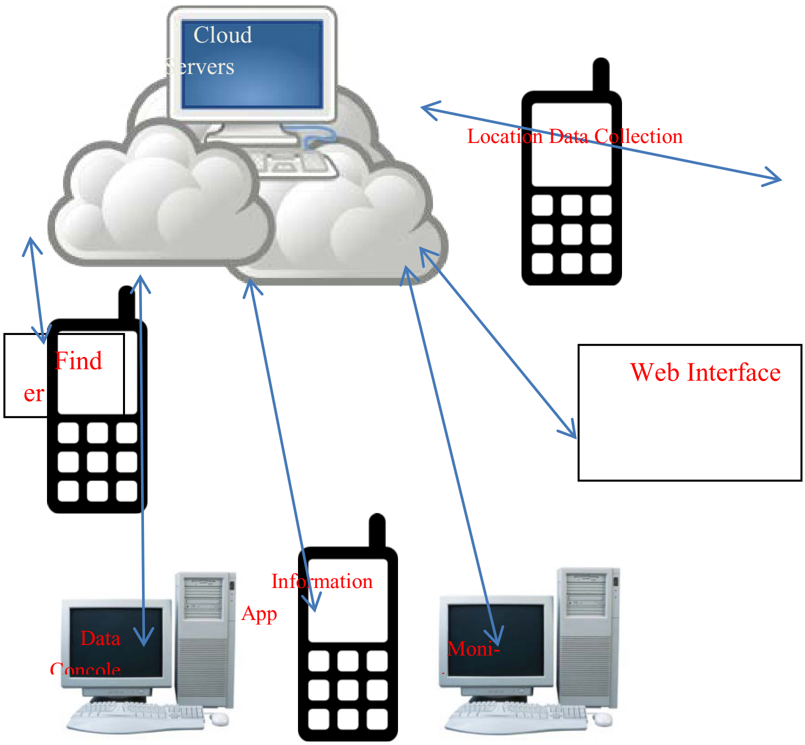

Fig. 1. The BARMOTIN System

want to enjoy the beaches and popular entertainment but they may want to know about the historical and cultural events that occurred at any particular location they are visiting. This app uses both conventional menus and voice commands for navigation. The user has the option to use voice commands instead of the menus. This app requires an email address and a user name in order to log into it. One of the features of the Information app is the proximity historical and cultural component. This component, once started, runs in the background and when the user approaches any location that is of historical or cultural significance he or she is alerted. The user then has the option to view data about the particular location. This may be in the form of text, graphics or video. The provided information includes the contribution to the Barbadian society and what it would have been like to live back in that era. The user may, due to bandwidth constraints or expense, choose to save the location in their favorites list. Later, when the users get to an area that has WIFI connectivity or a computer with internet access, they can view the data about the locations they have saved. The advantage of this feature is that when the visitor returns to their country they have a record of the places that they visited.

Another component of the Information app is the amenities finder. This component enables the user to find specific services that are in close proximity to where he or she is situated. This component also allows the user to find the nearest place of worship according to their religious persuasions and denomination. If a medical situation arises, the user can use this component to locate the nearest doctor with the specialty that they require. The user can locate the nearest dentist as well as any nearby pharmacy. This module also finds the nearest banks by type and other essential places like post offices and supermarkets. See figure 2.

This component is not a voice driven navigation system but provides an interactive map that changes and gives directions in text form as the user moves to the desired destination. This component also provides all of the contact information for the professional services, such as doctors and dentists, stored within the system so that the user may call ahead before their arrival.

Another component of the Information app is the emergency assistance component. One of its primary functions is contacting the police. This can be done in one of two primary ways. The user can type a message and send it if they have time or they can just press the police icon. The user can also say the word *police* if they have the voice commands feature activated. In the latter two cases, an automated distress message is sent. Included in the messages is the location of the user. As soon as the message is sent a tracking process is activated in the background. This is done so that if the person is moved and the phone is still on, the police can still track them. This component also allows the user to request an ambulance or mechanical assistance in the event that the vehicle experiences technical problems.

The last component in the information App is the dictionary of Barbadian words and sayings. This component is both audio and visual. The user has the option to hear how the word or saying is spoken in the native vernacular. It also gives the context in which the word or saying is used and the historical or cultural anecdote surrounding the word or saying.

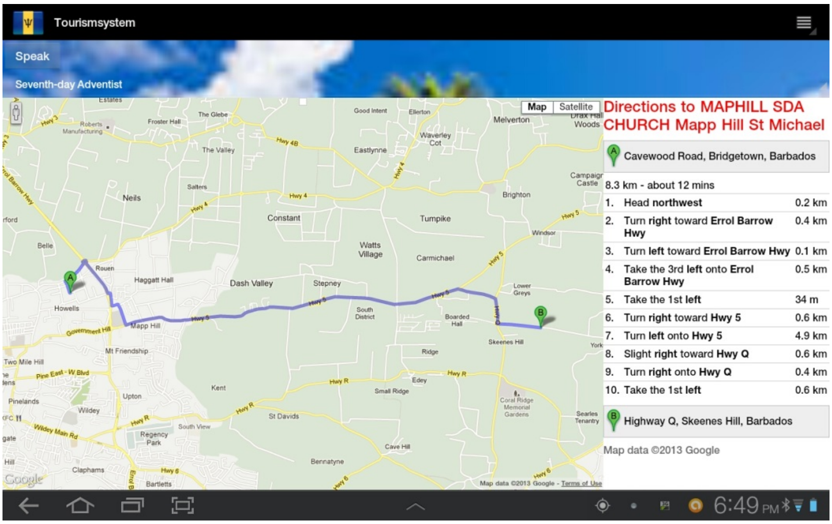

Fig. 2. Information App Showing Directions to an SDA Church

4.2 The Location Data Collection App

This is a mobile app that is used to enter the geographical data for each location and or service that is recorded in the system. The users who are collecting the data go to the relevant location and key in the required information such as the name, address, contact number and location type. Before the information is entered, the relevant data is gathered from a variety of sources such as the surrounding community or from telephone listings. This app only provides the statistical data about the locations but does not upload any historical or cultural data since this is performed by another module.

4.3 Cloud Servers

This system consists of three internet connected servers that form the core of the system. One of the servers is used to run all of the restful services which are the driving force behind the system. The restful services and Java programs provide the communication between the other servers and the apps. The second server is used as the database server and this holds all of the data that is relevant for the working of the system. The third server is used as the monitoring server for the emergency assistance component of the information app. This is a Microsoft Windows system but the operators can access it with any tablet that has remote desktop access.

4.4 Data Entry Console

Due to the time it takes to create a web page, it would be time consuming to manually create a web page for each location that is added to the database. This component allows the user to type the document in text form using a text editor. The user can also insert pictures. The system then converts the added data to HTML and uploads it to the relevant servers. This console can be used to add words or sayings to the database and has the ability to record the user as he or she says the word or saying. The user can listen to the recording and if they are satisfied, they can upload it to the relevant servers. This console is also used to upload any recorded video.

4.5 The Finder App

This is a mobile app that will be used mainly by the police and the mechanical teams that respond to emergency calls. Each team will have a unique key that they will enter into the finder app. This will allow the monitoring station to track where the police or mechanics are so that when a call comes in, it can be assigned to the nearest team. When a call is assigned to a team it pops up on their screen and once they accept it, a message indicating that help is on the way is sent to the user. During that time, the user can send updates on the situation which will go to the assigned team and to control. When the matter has been settled the assigned team will close the case on their app. This app has an interactive map that changes as the team moves toward the distress location or if the person that made the distress calls has moved to a different location. This app uses both conventional menus and voice commands.

4.6 The Monitoring Station

This is used primarily to monitor the system for any emergency requests submitted by the users and to pass them on to the relevant emergency departments. Each department will have their own monitoring station and the central monitor will be used to pass cases on. The operator can open a chat session with the user and apprise them of the progress of the emergency response. This system also displays a map with the location from which the request comes so that help can be directed to the correct location, see figure 3. This is especially helpful for visitors who may not know where they are. The system for each department has a map to show where each of their teams are at any given time so that that closest team can be assigned the case.

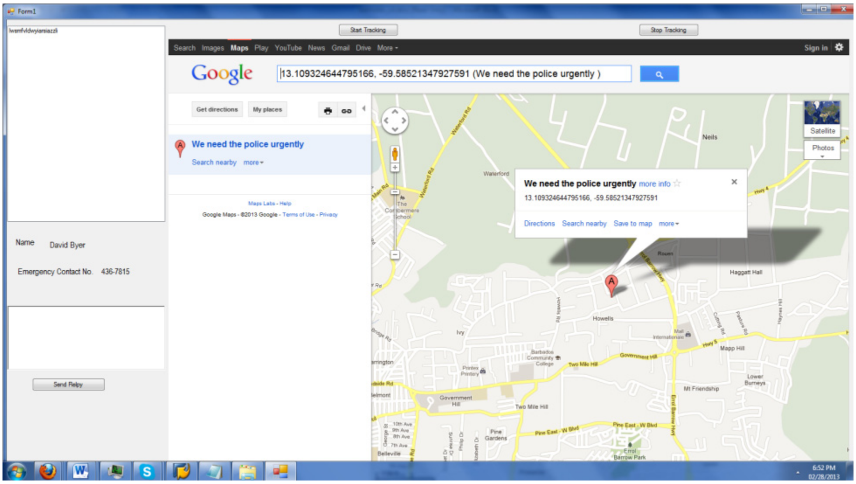

Fig. 3. Monitoring Station Showing a Request for Police

4.7 User Web Interface

Each user that uses the system must register and create an account, on the system's web site, before they can use the system. When the users register they have access to the information app which they can download. During the registration process, the user provides emergency contact information which can be used in the event of an emergency. The interface is also used by the user to maintain passwords. This is the interface that the user will use if he or she wants to view sites or locations that they have saved while they were out visiting and did not have the time to review.

5 Progress

The system is approximately 90% complete. The development process has now entered the data gathering phase. This entails collecting the geo coordinates of all the locations which will be featured on the system. This also involves collecting historical and cultural data and contact information where applicable on the sites to be added to the system.

6 Testing

BARMOTIN is now in the preliminary testing phase where all of the modules are being tested separately and then as a complete system. As the data is being gathered, each component of the system is being tested with that data. With the data collected so far the system has performed as expected.

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Usability Study of Icon Designs with Social Network Functions

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Abstract. The social media and related applications were developed and spread fast in our daily lives. Many users of social network sites (SNS) would use social network functions to communicate with their friends, such as share, like (or dislike), check in, upload interesting information to website, etc. Research on visible icons design in SNS user interfaces were one of the most important direct manipulation research issues. Moreover, how the privacy setting in different interaction model were discussed in this study. The results showed that: (1) The well-designed icons illustrated higher concreteness, less complexity, higher familiarity and suitable semantic distance than others; (2) There existed higher privacy setting in personal photo content than landscape photo content; (3) The design element used with most highest percentage was the "man image" because the functions were related to friends' photos and popular users' photos in the photo sharing Apps; (4) Different privacy setting considerations were dependent on different interaction models and scenarios.

Keywords: Usability Study, Icon Design, Social Network Function, Privacy Setting, Kiosk User Interface.

1 Introduction

The new and real time social interaction lifestyle has arrived by means of popular social platforms and mobile technology built in portable devices. More than 10 million people in Taiwan have Facebook account, and almost one billion people are using Facebook around the world. The influence to users' lifestyle has becoming an important research issues by integrated different disciplines. There is different research methods used in social media and applications. Not only the sociological and psychological research for usage motivation and Internet addiction, but also the interface design consideration and usability evaluation are discussed in recent years. The social media and related applications were developed and spread very fast. Many social network sites (SNS) users would use social network functions to communicate with their friends, such as share (e.g. photos, videos, links), like (or dislike), check in

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 355–362, 2013.

(e.g., restaurant, popular place, and school), upload interesting information to website, etc. The privacy setting is another important factor of social media usage - to interact with the SNS in public place or personal use. The visible icons design in SNS interfaces were the direct manipulation issues and quick feedback in usage. “Direct manipulation means that people feel they are controlling something tangible, not abstract” (Apple, 2010). According to the good interface design principles, the interface visibility and affordance consideration could be transferred and applied to icons appearance design and internal semantic distance. This research study is constructed based on four aspects including photo sharing Apps icons, grounded theory for users' icon-function cognitive abilities, icons usability evaluation, and SNS privacy settings. The research purposes are: (1) to exam the icon relationships of photo sharing Apps with semantic distances, concreteness, complexity, and familiarity; (2) to discover SNS privacy setting behavior; (3) to construct the social share interface with grounded theory analysis; (4) to compare the different usability consideration of different SNS platforms and interactions.

2 Social Network Service in Mobile User Interface

Social network service (SNS) stands a critical role in our new mobile life, and the content generated across different function features and platforms were spread fast if the content is valuable or interesting. Design research could be contributed to different function applications based on good interaction design concepts, such as popular interface design principles, cognitive design suggestions, cross social service design research, and scientific user corporation platform investigations (Preece & Shneiderman, 2009). This research study was conducted to help investigate the icon designs of basic social functions with usability research on mobile application, and previous research work of commercial Kiosk interface design (Chen, Hsiao, Chen, Huang, & Wang, 2012) for icon designs of integrated social functions.

3 Icon Design on Mobile and Public User Interface

A good icon design represented the common popular sense for clarity and well identification interface communication (Kolers, 1969; Marcus, 1984). The icon attribution categories were defined to representational, abstract, and semi-abstract aspects (Blattner, Sumikawa & Greenberg, 1989); and icons' features could be analyzed with four dimensions of “concreteness”, “visual complexity”, “familiarity” and “semantic distance” (Isherwood, McDougall & Curry, 2007; McDougall, Curry & de Bruijn, 1996, 1999, 2000). There was user cognition tasks built based on original and revised icons, and recorded the confirmatory responses and accuracy data during the experiment period (Schröder & Ziefle, 2008).

3.1 The Experiment Process of Mobile Application Icon Design

The icon design in this study was addressed based on four dimensions (Isherwood et al. 2007) and 42 participants were asked to draw their ideal icons of five functions determined by experts within a focus group.

There were four popular photo sharing application ranked by Appstore users and selected to be the samples of features established and icons analysis. The first step was to create the function flows of photo sharing applications and information structures. The next step was to analyze the icon's attributes based on four dimensions (McDougall et al., 2007). A focus group of three user interface design experts was set to discuss these samples.

The experiment was a between-subjects experiment design and the participants were randomly assigned to identify one of the four applications. There were twenty participants including eight males and twelve females in the experiment. After the icon recognition experiment, another twenty-two participants were asked to draw the five ideal function icons as they thought (see Figure 1). The first stage of this research study were to collect forty-two users' icon drawings pertaining to the five functions determined by experts from the popular photo sharing applications.

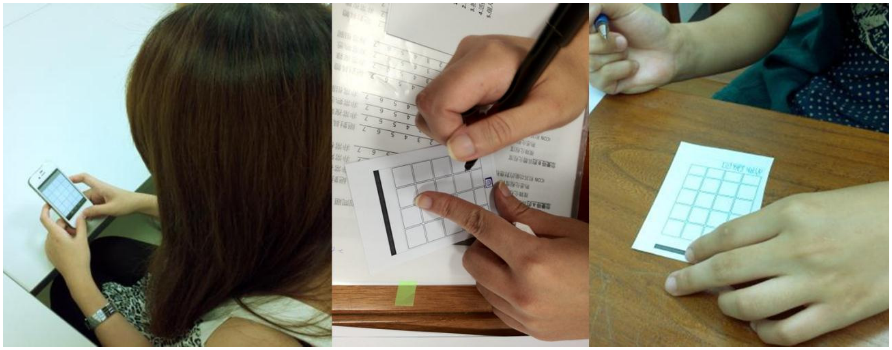

Fig. 1. The experiment process

3.2 The Analysis of Mobile Application Icon Design

The four dimensions mentioned before include "concreteness", "visual complexity", "familiarity" and "semantic distance". There were analyzed by the descriptive statistic and correlation analysis. The appropriate icon design (in this case, the camera icon with the score of 6.8 in a 7 point Likert scale) should be viewed as having the score of higher concreteness, less complexity, higher familiarity, and suitable semantic distance than others. The five primary functions (see Figure 2) were "all photos", "friends sharing photos", "take picture", "friends' activities" and "personal profiles." The lowest semantic distance icon was "friends' activities" (i.e., it had the score of 2.4), which presented the message and man-like image to represent the meaning of what activities friends did or what messages friends left on photos.

Fig. 2. The redesign five main function icons

The four dimensions measurement was discussed with correlation analysis (see Table 1). There were 20 icons from four analyzed applications and 4 set of perspective views (also see Figure 2) used for the testing of dimension correlation. The results were illustrated as the followings: (1) The "semantic distance" had significant positive correlation with "concreteness" and "familiarity"; (2) The "semantic distance" had significant negative correlation with "visual complexity"; (3) The "concreteness had significant positive correlation with "familiarity"; and (4) The "visual complexity" had significant negative correlation with "familiarity." The results were almost the same as the research conducted by Isherwood et al. (2007). The only difference is that the "semantic distance" had significant negative correlation with "visual complexity." The difference can be explained that there were only twenty participants to help evaluate the icons. If more participants were invited in the experiment, the results can be different.

Table 1. The correlation analysis matrix of four variables

		Concreteness	Visual complexity	Familiarity	Semantic distance
Concreteness	Pearson Sig.(two-tailed) Sum	--	--	--	--
Visual complexity	Pearson Sig.(two-tailed) Sum	-0.263 0.214 24	--	--	--
Familiarity	Pearson Sig.(two-tailed) Sum	0.686 0.000** 24	-0.593 0.002** 24	--	--
Semantic distance	Pearson Sig.(two-tailed) Sum	0.715 0.000** 24	-0.523 0.009** 24	0.647 0.001** 24	--

** Significant at the 0.01 level.

3.3 Mobile Icon Drawing Analysis by Grounded Theory

Figure 3 showed that results of participants' drawings. The grounded coding of icon designs was on the man-like image and the concrete image of noun-based function description. About the "activities" function, there were several different representation designs, such as man and messages, messages, to do list, flags, and comment gesture, etc. The drawing illustration had been affected by the function description. The drawing task should be revised in the future study. It is suggested that before the drawing tasks, there should be simulation interfaces designed for participants to help them get familiar with the task.

Fig. 3. Participants drawing results examples

3.4 Public Icon Design of Social Recommendation and Like Mechanism

The quality of social network content which users shared or enterprises announced information was associated with the users' motivation to access the further action initiative or not. Understanding the popular content distribution patterns which could be spread across different sites and platforms will be the commercial and advertisement opportunities (Benevenutoy, Rodriguesy, Cha, & Almeida, 2009).

According to the previous study, the social sharing function has positive effects towards users' purchasing behaviors. The function of "Like (+1)" and "friends' recommendation" may attract more users' attention of the products than official social website sharing (Chen et al., 2012). The icon designs for public SNS user interface (see Figure 4) had different consideration from mobile user interface. The "privacy consideration" from signing into the system to upload personal photos stood the critical role in the task process. On the other hand, the task consistency with the physical public Kiosk and the displayed user interface could seriously affect user experience. The immediately feedback of commercial activities built on the interaction scenario would be the most powerful opportunity to catch consumer's attention. The opportunity will be the strength of public interactive SNS related Kiosk if the user interface design and task design are good enough.

Fig. 4. Social recommendation and like mechanism (Source: Chen et al., 2012)

4 The Comparison of Privacy Setting on Two SNS User Interfaces

There were two experiments conducted on photo sharing Apps of mobile phone and photo share function of public commercial Kiosk (Chen et al., 2012). A total of forty-one participants who have SNS usage experience were asked to answer the questionnaire of privacy setting. On the other hand, twelve participants who joined the experiment and conducted tasks with the simulated SNS Kiosk user interface had been interviewed regarding the privacy settings. Figure 5 showed that forty-one participants' privacy setting trends from the photo content of "landscape without people" to "personal pictures." The x-axis represented the privacy setting of "public of everyone (1.00)", "extend from friends circle (2.00)", "only friends circle (3.00)", "special friends (4.00)" and "absolutely private (5.00)" (Facebook website & Google+ website, 2013). According to the results from one-way ANOVA of photo contents and post hoc test (see Table 2), the privacy setting trend of mobile photo sharing behavior followed the photos content from public sharing (i.e., landscape picture) to private (i.e., personal picture) ($F=17.849$, $P<0.01$).

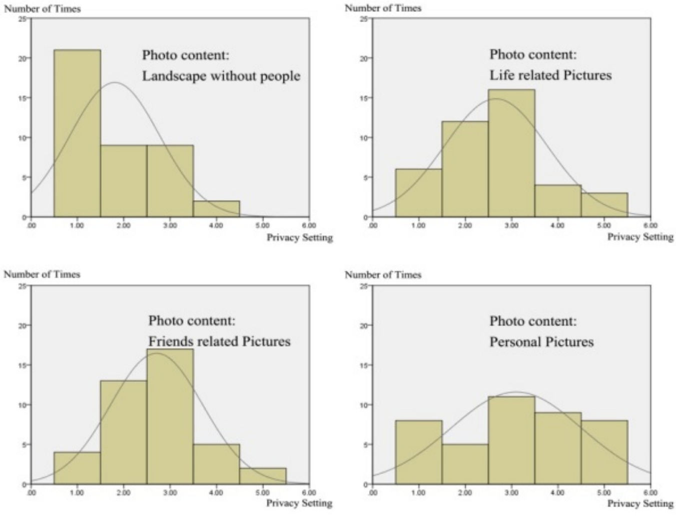

Fig. 5. Privacy setting in different photos content

Table 2. The results of one-way ANOVA regarding photo contents difference

Variable	Level	Mean	S.E.	SS	df	MS	F	P	Post hoc
	1.Landscape	1.733	0.151						
Photo	2.Life	2.632	0.178	36.388	3	11.896	17.859	0.000**	4>3=2>1
contents	3.Friend	2.685	0.160						
	4.Personal	3.049	0.227						

** Significant at the 0.01 level.

Regarding the privacy consideration of public Kiosk, the first priority issue was users pay more attention to the security protection mechanism when they login to the system. There were no different content levels like photo sharing mobile interface, but the basic users' needs of commercial Kiosk service was obvious on personal information security. No matter uploading photos to official Facebook website or logining into personal registration accounts, the public Kiosk user interface should have serious privacy setting and protection mechanism.

5 Conclusion

This study is an integrated research pertinent to public commercial Kiosk user interface and mobile application user interface. The icons design research was conducted to investigation the different dimensions and use situations. Finally, the research had compared two SNS user interfaces with the consideration of privacy setting. It was the authors' intentions to connect user cognition and sociological behaviors in this study.

The results generated in this study showed that: (1) The well-designed icons illustrated higher concreteness, less complexity, higher familiarity and suitable semantic distance than others; (2) There existed higher privacy setting in personal photo content than landscape photo content; (3) The design element used with most highest percentage was the "man image" because the functions were related to friends' photos and popular users' photos in the photo sharing Apps; (4) Different privacy setting considerations were dependent on different interaction models and scenarios. In the further research, the quantified statistical research of user behaviors and usage motivation about SNS user interface and platforms experience can be further explored.

Acknowledgements. This study is conducted under the financial support by the National Science Council with the grant number of NSC 101-2221-E-011-002-MY2 (101).

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An Analysis of Smartphone Size Regarding Operating Performance

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Abstract. An increasing number of electronic devices employ touchscreens as the operating method. Among these devices, smartphones have exhibited the most rapid development. To achieve more impressive visual effects, the size of smartphone displays has gradually increased. However, the resulting disadvantage is that these devices cannot be operated using one hand. In situations where users must operate the phone with one hand, some screen areas cannot be reached by their thumb. Thus, the demand for one-handed operation remains. This demand is related to operating convenience, which is obviously not provided by existing products. This study analyzes touchscreen cell phones with varying screen sizes, from 2.55 to 5.3 in, currently available on the market to examine the efficiency of one-handed operation by investigating four operating directions, that is, diagonal, horizontal, vertical, and center-cross. In addition, a customized application was developed to record the operating sequences, frequencies, numbers of errors, and positions of errors to understand the effect that display sizes have on one-handed operation. According to the analysis results, 4-in touchscreen cell phones generated the fewest operating errors, and 3-in touchscreen cell phones provided the shortest operating time. To obtain optimal visual effects, the implementation of 4-in screens for touchscreen cell phones may be the best option for one-handed operation.

Keywords: touchscreen, smartphone, interface design.

1 Foreword

Next-generation products such as smartphones and touchscreen tablets have continuously stimulated consumer demand (Len 2012). Users commonly play games, watch videos, and browse webpages using their smartphones, which also enhance users' interpersonal relationships and emotional communication (Lee and Lin 2006). Considering the number of sales, consumers desire smartphones with larger screens and a higher display quality (Lin 2012). Endeavoring to satisfy consumer desires, manufacturers have continued to create cell phones with larger displays and higher resolutions (Chang 2006), rapidly popularizing touchscreen smartphones. Consequently, larger and more detailed screens have become the primary developmental

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 363–372, 2013.

trend. Although large-size screens increase users' comfort when using the devices, if screens exceed a certain size, such as a 5.3-in screen, the ability to operate the device with one hand is sacrificed (David 2011). However, the one-handed operation of a large-screen cell phone poses a risk of users dropping the phone because of an insecure one-handed grip. Furthermore, as shown in Fig. 1, if users hold a large-screen cell phone with one hand, some screen areas cannot be reached easily with their thumb (Dustin 2011).

Fig. 1. Thumb-tapping range (Dustin 2011)

According to previous research (Chang 2006), the optimum strategy for improving cell phone operation is to design procedures that can be completed using only one hand. For convenience, most people operate devices such as remote controls, cell phones, and PDAs with one hand (Shih 2009). In addition, most users performing dialing and conversing operations using only one hand when moving around (Karlson et al. 2006). Surveys regarding the behavioral environments of cell phone operation have shown that cell phones are primarily used when users are moving and standing, when one-handed operation is more comfortable. Whereas when resting places are provided or when users are seated, the higher environmental comfort facilitates increased two-handed operation. However, in most situations, only one hand is used for operation (Karlson et al. 2006).

Existing studies regarding smartphone interfaces have focused on the button size and spacing (Chang 2011), the button shape (Chen 2002), touchable areas (Huang 2010), and how the button sizes and input methods are related to gestures (Lee and Kuo 2004). These studies analyzed the elements of user interfaces (UIs), but did not discuss issues related to various sizes. Therefore, this study investigates and conducts experiments regarding existing touch models, identifying the optimal display size for one-handed operation of smartphones of varying size. Furthermore, this study examines the influence of the directions of thumb movements by analyzing operating efficiency and error rates.

2 Literature

2.1 Touchscreen Interface

Although touchscreen technology emerged in the 1970s, it was not popularized and incorporated into people's lives until recently. The reasons for this recent popularization of touchscreens include the widespread use of flat-panel displays, the development of manufacturing technology, the decline in costs, the advancement of materials technology, and the emergence of UIs specifically designed for touchscreen operation. These factors have prompted manufacturers to choose touchscreen inter-faces as the major UI for their products. From a user perspective, touchscreen interfaces provide a useful design that is not restricted by technological attractiveness.

A marketing research survey conducted in the United States in 2009 indicated that more than 95% of adults under the age of 45 considered the touchscreen interface to be the most usable human-machine interface, and more than 80% of the interviewees believed that an operating method using a touchscreen provides a more intuitive and usable experience (Pen 2009). Therefore, we can infer that the touchscreen interface, because of its intuitive design and applications, will remain significant for product development and designs that emphasize user experience.

2.2 The Relationship between Cell Phone Operation and Palm Size

When designing handheld devices, to ensure that users can stably and comfortably grip the device, a standard palm size must be obtained before beginning the actual product design. Therefore, palm sizes have a significant influence on handheld devices (Huang 2010). Users with large palms experience greater difficulty operating small handheld devices, whereas users with small palms cannot easily operate large handheld devices. According to research regarding the operation of traditional cell phones, when operating or inputting text into a standard cell phone with physical buttons, changes in button position do not cause significant differences in operating speed or accuracy (Chang 2007). In addition, most relevant studies used a fixed cell phone size for experiments; even if size was among the concerns of a particular study, the experiments tended to focus on button sizes and the spacing between buttons (Huang 2011). Studies that concurrently discuss cell phone size and the directions of thumb movements are scarce.

3 Experimental Design

Using smartphones of various sizes, this study investigated touchscreen interfaces and conducted experiments using a customized application to examine the efficiency and accuracy of various smartphone sizes. Before the experiments begun, the participants' palm sizes were measured for subsequent analysis of the effect that palm size has on operating efficiency for smartphones.

Because Android is the operating system with the largest market share, various Android smartphone models of varying size were selected as the operating devices for the experiments. Furthermore, a customized application featuring an interface scaled to the smartphone size without altering the proportions was developed. Most of the study participants were users in Asia. When the participants were holding the cell phones, the operating errors that occurred were caused by their personal habits and the adaptability and responsiveness of the device. Therefore, future studies should record the experimental procedures to collect data to solve this problem.

3.1 Experimental Equipment

In this study, various sizes of smartphones were employed to analyze the effect that size has on operation. A total of 10 smartphones of differing size were obtained, and a customized application was designed for the Android operating system to provide a UI that conforms to the experimental settings. Fig. 2 shows the differing display sizes of the various models, facilitating a comparison of the frame and screen sizes of the 10 selected smartphones.

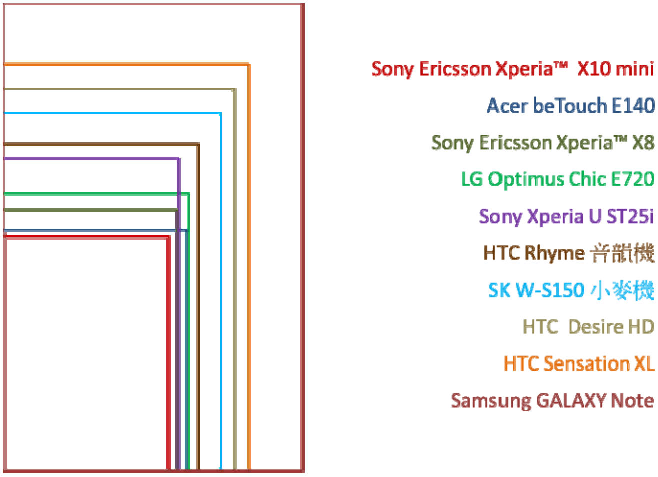
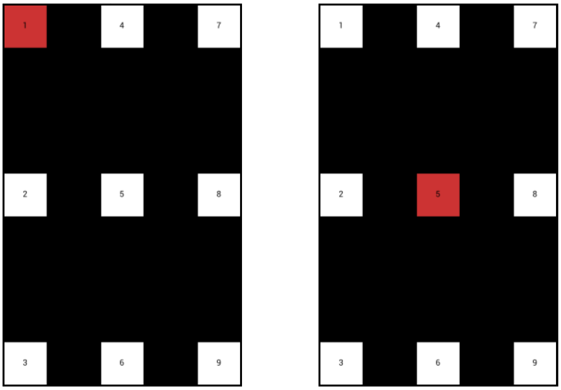


Fig. 2. Frame and screen comparison

3.2 UI Design

The operating area of the test application employed the entire screen. Fig. 3 shows the configuration of the application interface displayed throughout the experiment. Before the participants operated the devices, an operation sequence was hinted ran-domly. Considering the example shown in Fig. 3 (a), the participants were instructed to tap the position denoted by the red block, followed by the next location shown in Fig. 3 (b). The participants followed the hints until all the red blocks were tapped.

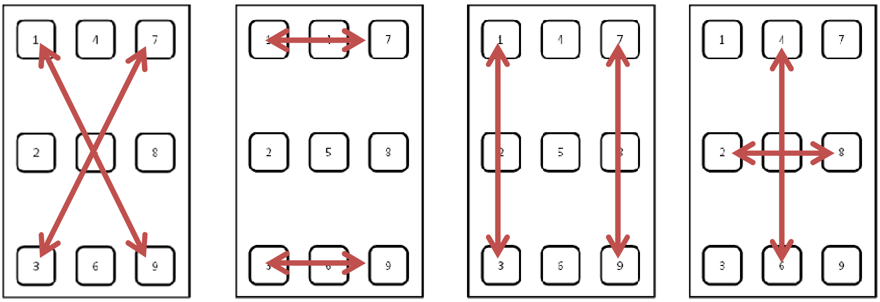


(a) Tapping 1 (b) Tapping 5

Fig. 3. Configuration of the application interface

3.3 Experimental Procedures and Setup

The participants' palm width and thumb lengths were measured before the experiment, during which the participants were tested in a randomized order using 10 smartphones. A questionnaire was issued to the participants after the test to collect their reflections, opinions, and comments regarding the possible causes of smartphone operation errors. The data obtained from the questionnaire were compared with the experimental results. A sequence of four operating steps was designed for the thumb-moving experiment; this comprised the (a) Diagonal direction, (b)Horizontal direction, (c) Vertical direction, and (d)Center-cross direction, as shown in Fig. 4. Using the diagonal direction (a) as an example of the experimental operation design, in each setting, two random figures were added before the to-and-fro actions, which were tapping to and fro from buttons 1 to 9 and buttons 3 to 7. This method was adopted to establish three sets of circular actions including buttons 1, 3, 7, and 9, and the operating sequence of each setting was randomized.



(a) Diagonal direction (b) Horizontal direction (c) Vertical direction (d) Center-cross direction

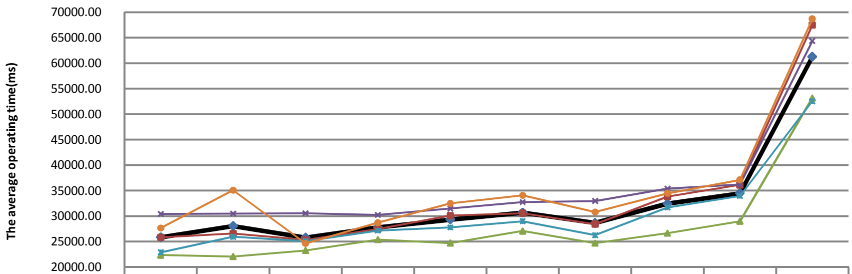
Fig. 4. Scheme of the operating sequence

4 Experimental Results

All the participants of the experiments were right-handed. Their average palm width ranged between 18 and 22.5 cm, and the average thumb lengths ranged between 5.5 and 6.6 cm. The experimental results can serve as a reference for users with a palm width and thumb lengths within these ranges.

4.1 Operating Time for Cell Phone of Differing Size

Fig. 5 shows the analysis results for the operating time of various cell phones. Larger cell phones required longer operating times. The operating time for a 5.3-in cell phone was significantly higher than that for the other cell phones.



	2.55"	2.8"	3"	3.2"	3.5"	3.7"	4"	4.3"	4.7"	5.3"
Average	25844.60	28048.95	25786.90	27802.65	29323.40	30700.75	28645.60	32427.50	34487.55	61241.90
Subjects1	25839.75	26601.75	25315.50	27484.50	30093.50	30573.75	28439.75	33862.00	36129.75	67474.75
Subjects2	22369.25	22105.75	23300.00	25413.75	24734.00	27084.75	24733.25	26665.00	29013.50	53166.50
Subjects3	30426.75	30494.75	30552.50	30240.00	31493.00	32766.75	32964.75	35404.50	36219.75	64352.50
Subjects4	22911.25	25949.00	25118.75	27164.00	27804.75	29001.75	26276.25	31722.00	33948.25	52536.25
Subjects5	27676.00	35093.50	24647.75	28711.00	32491.75	34076.75	30814.00	34484.00	37126.50	68679.50

Fig. 5. Operating time for cell phones of differing size

4.2 Analysis of the Number of Errors for Cell Phones of Different Size

After the participants had finished operating the smartphones according to the experimental procedures, the number of errors generated on each cell phone was compiled in statistical form and analyzed. The data showed that the cell phone size was not directly proportional to the error rates. The lowest error rate measured was for the 3.2-in cell phone, which had an average of 0.5 errors for each participant. This was followed by the 4-in cell phone with an average of 0.6 errors. The highest error rate measured was for the 5.3-in cell phone, which had an average of 1.55 errors for each participant.

In addition, the 10 smartphones were categorized into three size groups. Smartphones that were smaller than 3 in were categorized as small, those between 3.2 and 4 in were categorized as medium, and those larger than 4.3 in were categorized as large.

Table 1 shows the number of errors for each experiment; the results show that operations in the diagonal direction resulted in the highest number of errors. This suggests that diagonal operations were more difficult for the participants, especially with larger smartphones. The second highest number of errors was for operations in the center-cross direction; however, smaller rather than larger smartphones tended to generate center-cross operation errors.

Table 1. Number of errors

	3" and under	*3.2" to 4"*	*4.3" and above*	*Total*
Diagonal direction	11	18	52	81
Horizontal direction	23	18	18	59
Vertical direction	32	17	13	62
Center-cross direction	37	23	13	73
Total	103	76	96	275

4.3 The Error Distribution for the Interface

The areas where errors occurred were divided into locations based on the application interface. The screen interface configuration shown in Fig. 6 was used to compare the total errors in all locations for cell phones of various sizes, as shown in Table 2. The 10 smartphones were also categorized into three size groups for analysis, as explained in the previous section.

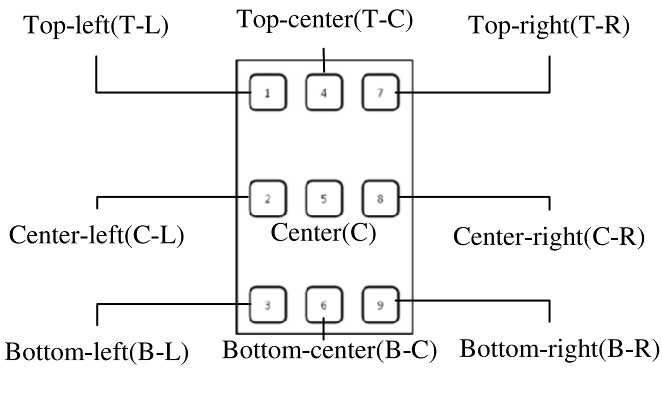


Fig. 6. Configuration of the screen interface locations

The findings listed in Table 2 are as follows: (a) For small cell phones, C errors were more likely to occur, and B-R errors were the least likely to occur; (b) for medium-sized cell phones, the number of C-R errors was the highest, and the number of B-R errors was the lowest; and (c) for large cell phones, the number of B-R errors was the highest, and that of T-C errors was the lowest.

Table 2. Sum of errors for all locations and sizes

Top-left 0.5	Top-center 0.75	Top-right 0.475
Center-left 0.75	center 1.125	Center-right 0.725
Bottom-left 0.25	Bottom-center 0.45	Bottom-right 0.125

(a) Small cell phones

Top-left 0.35	Top-center 0.575	Top-right 0.25
Center-left 0.575	center 0.7	Center-right 0.65
Bottom-left 0.25	Bottom-center 0.275	Bottom-right 0.175

(b) Medium-sized cell phones

Top-left 0.5	Top-center 0.15	Top-right 0.625
Center-left 0.675	center 0.6	Center-right 0.3
Bottom-left 1.25	Bottom-center 0.3	Bottom-right 0.4

(c) Large cell phones

4.4 Time Required for Movements in Various Directions

Fig. 7 shows the time required for movements in various directions; the results indicate that T-R>B-L operations required comparatively more time. This may be because of the longer moving distance, or because the right-handedness of the

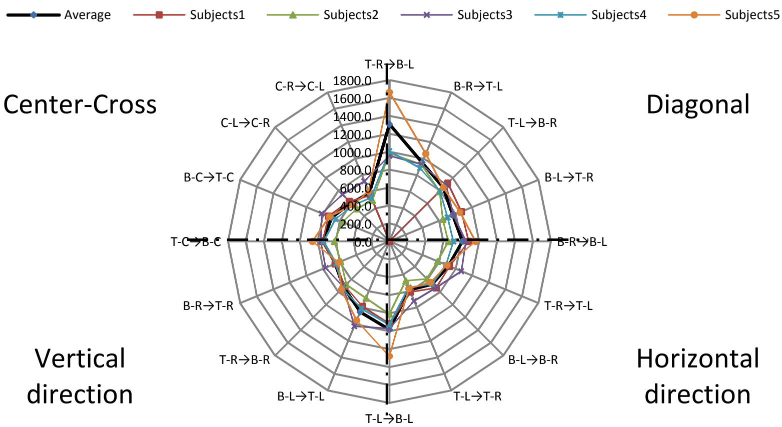


Fig. 7. Time required for movements in various directions

participants obstructed the movements. The directions that required more time included B-R>T-L, because of the longer distance and movement obstruction, and T-L>B-L, because these two locations could not be easily reached with the participants' right thumb; they had to adjust their hand position to complete the movement. The fastest movement in this figure was T-L>T-R and C-R>C-L, which are locations above the center of the screen, which is more reachable with the thumb when holding a cell phone.

5 Conclusions and Recommendations

The experiments were followed by a questionnaire survey regarding the participants' preferences. The participants all agreed that cell phones ranging between 3 and 4 in were more user-friendly. The 3.2-in cell phone was rated the optimum size. This may be related to the experimental results that showed superior operating speeds for the 3- and 4-in cell phones. Finally, the participants were instructed to select their favorite cell phones without considering the number of errors and operating speed. Their choices were not restricted by size because although small cell phones can be comfortably gripped, large cell phones provide superior visual effects. However, most of the participants considered large cell phones difficult to hold with one hand.

Smartphones measuring 3 to 4 in could be operated with greater efficiency and accuracy. The operating time increased for smartphones larger than 4.7 in. Regarding error rates, operating errors were the least likely to occur in the bottom-right of the interface for all sizes of smartphones. To respond to future trends for developing large cell phones, interface or exterior designers can reference the results of this study. The researchers will employ the same methods to conduct research with a greater number of participants, including left-handed people, and analyze the participants' palm width.

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Mo-Buzz: Socially-Mediated Collaborative Platform for Ubiquitous Location Based Service

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Abstract. This paper describes a middleware platform for user-generated multimedia contents which facilitates visualization and communication of vector-borne diseases (dengue, malaria, etc.). It acts as a community platform, where diverse users from geographically distributed locations can collaborate to seek and contribute multimedia contents of such diseases and related issues (breeding sites, etc.). Some of the essential services supported by the system are display of live hotspots, timeline, multimedia and Twitter-feed visualization, and location based services for both users and authorities. As a proof-of-concept, dengue disease was selected to build services using this platform to observe its capabilities.

Keywords: Geographical information systems, information visualization, Mobile multimedia, interactive maps, middleware, user-generated contents.

1 Introduction

Dengue is a vector-borne infectious disease that has historically posed continued threats to populations living in both developed and developing countries. Dengue affects more than 50 million people in the world every year, in particular countries in the Asia-Pacific region that share more than 70% of the disease burden [1]. In Singapore, there were two serious outbreaks within the past 10 years, affecting 14,032 and 8,287 people in 2005 and 2007 respectively [2] [3]. Although various efforts were made to fight dengue in Singapore, the country remains vulnerable with an average number of 5, 000 dengue victims reported every year [4].

Unfortunately, there is no known vaccination or medicine that can prevent this infection. Hence preventing dengue, by destroying breading sites may be the best way to control this disease. Lack of information about breading site is one of the major problems in controlling these kinds of diseases. Authorities try to be aware about the real situation, but the resources are always a problem, especially in developing nations. Several applications have been developed to address this issue by introducing different information gathering and distribution mechanisms. However, one

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 373–382, 2013.

noticeable drawback of these systems is that they are more focusing on a selected subject, hence solutions have its own limitations related to that particular subject.

Our application stems from a recognition of the growing need to integrate epidemiological practices with health communication interventions – two processes that are traditionally thought to take place complimentary can now do so concurrently. In great measure, this innovation is attributed to the emergence of mobile phones and social media that are transforming the way public health is practiced. To reaffirm the preference for these technological preferences among our populations of interest, we surveyed middle-of-pyramid populations in three Asian countries – India, Singapore, and Vietnam – with a sample size of 1,000 from each country. Our survey found that mobile phones are among the top 3 preferred media for seeking health-related information, and that the demand for smartphones is poised to increase in India and Vietnam in the coming years. Similarly, social media are found to be of immense utility for keeping in touch with people, searching for information and sharing information. These findings, in concert with emerging needs in public health, lead us to identify the need for a system which enables citizens to track disease spread (search for information), contribute to surveillance efforts by engaging with health authorities (share information) and further disseminate health information through members of their social networks (keep in touch with people/share information) using simple mobile phones or smartphones.

Our solution is an attempt to create a platform that gives authorities awareness about ground situation. The system also creates an interactive channel between the general public and authorities. This also allows interactions with end-users in a structured-hierarchy or a flat structure depend on the situation. Hence this solution can be used to collect and distribute large range of data among diverse user groups. Instead of asking general public to engage, this platform gives opportunities for them to involve and solve problems themselves. Getting citizens more involved in the civic life and health of their communities is more effective in these kinds of situations, especially for resource limited environment. The bidirectional information floors are very important for such issues where it helps to have an equal and better understanding between the authorities and civilians, which will increase the civic engagement [5] in the long run.

2 Related Work

With the unprecedented growth of the internet and its increasing demand, diversity of standalone applications started to develop as web applications including, health [6] and geographical information systems [7]. In data visualization, map-based visualization is widely used to visualize geospatial data. Currently, Web-GISs are widely used due to its ability to obtain data from geographically distributed locations. Hence experiments are continuing to improve the usage of interfaces [8], and reduce the cost [9]. Further, visual health communication [10] is an emerging field because of its ability to help visualize the data in a friendly, interactive manner. Therefore, extensive studies have been done in order to create a health based communication platform and use of GIS when needed [9]. For fast spreading disease, GIS systems have been used to gather information to allow necessary actions to be taken quickly and decisively in a situation like SARS [11]. On the other hand, most of the current applications focus on centralized solutions [12].

On the other hand, most of the existing solutions focused on traditional methods, which has limited involvement of the social media or civic engagement [5]. Hence the focus of this project is to create a platform for such engagement that can be used for diverse of issues using different channels. Building social networks is one of the things that humans always fond of doing [13]. There are large numbers of information flows through social networks under different categories. Researchers have been analyzing these contents to have better understanding about the society under different aspects. For instance, Twitter is one of the famous social networking sites that can be used for above mentioned surveillance since it has a free and an open network. Use of such networks for various domains including heath purposes can be found in [14] [15] [16]. To facilitates the general public to contribute to surveillance efforts in the event of disease outbreaks [17], we have developed a platform, known as Mo-Buzz, which is focused on emergence of mobile phones and social media that will help to transform the way public health is practiced.

3 System Architecture and Its Features

The system is built upon open source technologies and mainly for mobile and web based application which can access through android platform or a browser. Android solution helps the main application by running as an agent on mobile devices. The users can report information in various forms (photo, audio, video, text, etc.) using mobile devices. The system also uses SMS technologies for feature phones. Web based solution is available for everyone; however, it has more features for authorities. The solution consists of two parts, which are interactive system for geospatial visualization and web forms for other details. The solution is developed with the aid of java related technologies, such as richfaces, jpa, javascript, and jquery. Server side of this system is supported by apache, tomcat, and mysql. Google map API is used for the interactive map while Google cloud is used to facilitate android based messaging solution. The overall system modules are shown in the Fig. 1.

The system can be divided in to three main modules based on their functionalities, which are content management, visualization, and personalized messages & alerts. Each of these modules has set of components that communicate to each other to facilitate attractive features.

3.1 Civic Engagement

This component provides the cutting-edge addition to existing PE efforts. The key idea here is to activate the general public to contribute to surveillance efforts in the

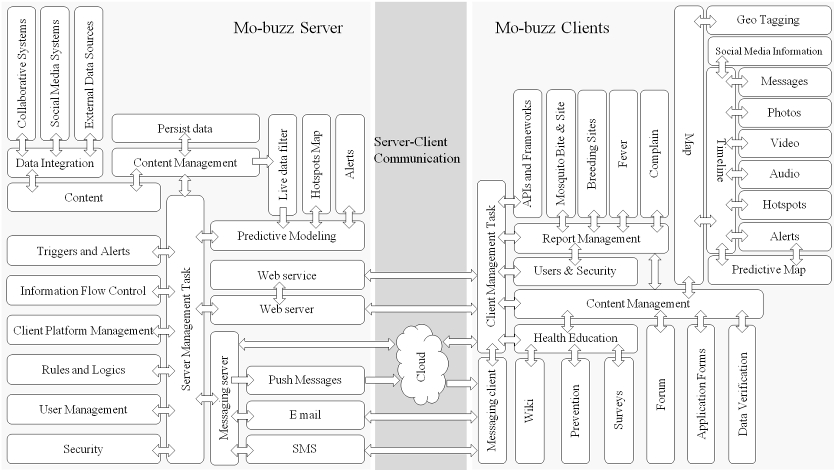


Fig. 1. System architecture

event of disease outbreaks. In this instance, citizens can report breeding sites, mosquito bites and Dengue symptoms using their smartphones in image (Fig. 2), video or text (Fig. 3) formats. These inputs are automatically reflected in the hotspot maps and can be accessed by health authorities for responding to citizen concerns as well as for initiating preventive actions in specific communities. The process is facilitated rapidly because of two reasons: a) mobile phone-based inputs from citizens are geo-tagged; and b) the Mo-Buzz system captures geo-spatial coordinates, time and date, and phone number of the contributor.

3.2 Content Management

The process of content validation comprises three categories, which are high, moderate, and low. These levels will define the reliability of the contents. Based on the reliability level of the data insertion mechanism, the filters are applied to the contents. If the category of the contents is high, then contents are directly available on the system. The content provided by authorities or registered users listed as high-reliable contents, which are fallen in to this category. The contents provided by the unregistered users are considered as low reliable data. Such data become available to users that listed as content validates. Users under authorities or registered users listed under “content validates” can access this content for verification. Based on the content's location, information is pushed to volunteers for verification. After the verification, contents can be fallen into the high or moderate category. If the content is verified by a user under the authority or reliable registered user, the content is ranked as “high” otherwise it will be ranked as “moderate” and will available to appropriate users for further verification. One or more users can verify the same content and all the ranks for the content are recorded in the system.

Users can voluntarily participate for the content verification and above verification is only applied to some selected categories of content such as photos, videos, and text messages. One main objective of the content ranking is to avoid unwanted, or fraud information reaches the authority. In reality, this will help to optimize the accuracy of the contents and will increase the civic engagement.

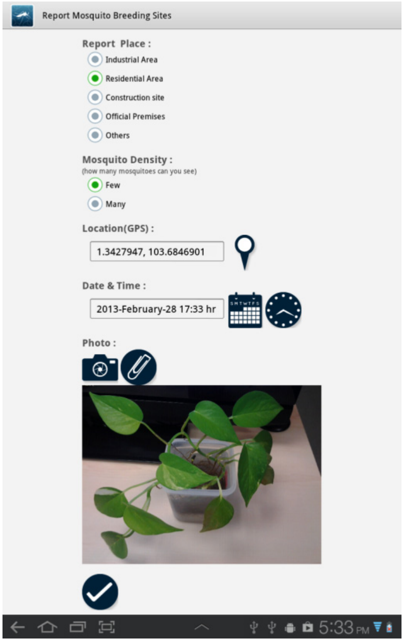


Fig. 2. Mobile app images report risk factors

Fig. 3. Report symptom using mobile app

3.3 Information Visualization

Visualization mainly consists with maps and forms. The main component of visualization is the interactive map. Most of the data in the system are geospatial data, which can be shown through the map. Visualization information can be divided into following categories:

Hotspots

Hotspots are real incidents (ex: reported disease). The interactive map highlights these incidents by circles, which show the incident's housing block (Fig.4). The color of the circle denote by the number of cases reported from each block as explained by the ledger. The visualization of the hotspots is based on the approved data by authorities. The centers of the circles are calculated by using each incident block's postal code.

The hotspots are used to provide exact location of the incident to the general public so they can arrange precautions based on their location. This visualization also gives a sense to different authorities about the next emerging incident clusters so they can plan and manage them accordingly.

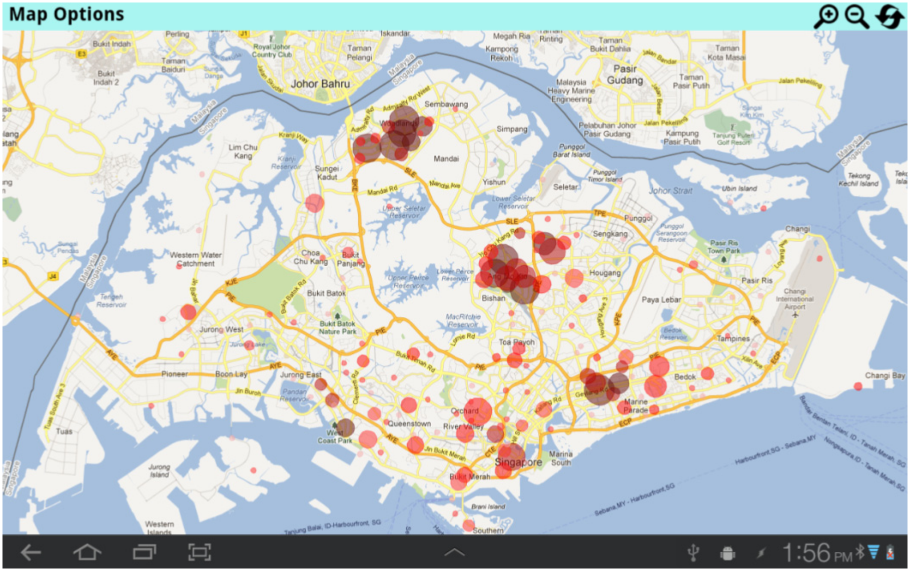


Fig. 4. Hotspots

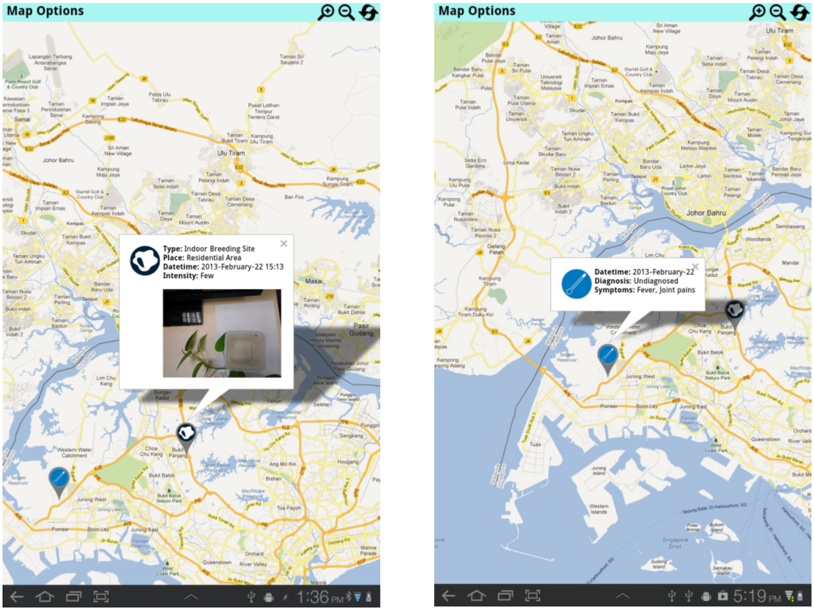
Multimedia Contents

Interactive map is encouraging its users (general public) to report about incidents or related information using several channels. Users can report this information by sending photos (a of Fig. 5), or messages (b of Fig. 5) as shown in Fig. 5. This will help authorities to identify possible important place that need to pay their attention. This will also simulate the reality about different places and trends of the society.

System will also allow its users to express their ideas through a forum. Application also allows selected user to act as ambassadors of the community or institute. They can also include messages to the system and these messages are considered as verified or reliable information.

Social Media

This system helps to create awareness by listening to the public conversations which are happening in the society. This is another way to get information about the real ground situation. The current version can listen to twitter feeds and filter information based on the user location and keywords. The system will display the associated conversations on the map according to their geographical location as shown in Figure 6. These feeds will offer suggestion to the authorities about the real situation on the ground.



a). Reported image of a breeding site **b).** Reported symptoms as text content

Fig. 5. User generated multimedia contents

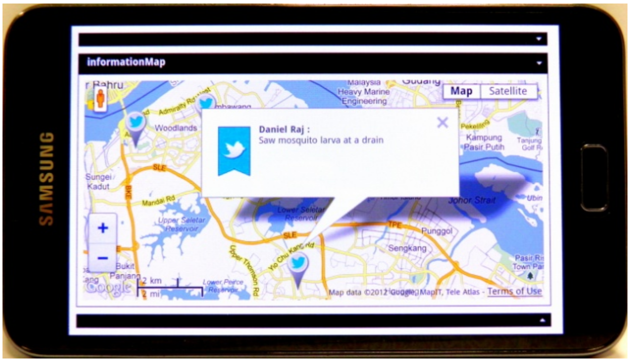


Fig. 6. Twitter feeds related to dengue disease

3.4 Personalized Messages and Alerts

The repository of outbreak information based on weather and citizen data is used to disseminate health messages to both, individuals and communities. At the individual level, citizens receive tailored messages based on their input to the system. For instance, a citizen reporting malaria symptoms or mosquito breeding site to Mo-Buzz will instantly receive a complete information guide on, breeding site or symptoms, and cues to various preventive actions. At the community level, the system will automatically send health education messages to communities/zones (Fig. 7) that are highlighted on the maps as possible hotspots. Public health surveillance efforts are thus used to generate and deliver health communication messages. At a fundamental level, the system acts as a catalyst between the citizen and the public health system where the contributions of each stand to benefit the other. Overall, the intention is to use Mo-Buzz for efficient and effective risk prevention and outbreak management. In addition to communication modules, the system is capable of sending alerts to citizens living in areas identified as potential hotspots.

Fig. 7. Mo-buzz education messages

Messages can be alerts, reminders, or any useful information generated by the system or authorized users. Personalized messaging is used to disseminate messages to end users according to the message settings. Users can select various options in the message registration process which uses by the messaging system. Messaging system uses both push and pull techniques according to the selected options. The proposed system always tries to avoid messages broadcasting. Instead, it pushes messages to users based on their location, message's priority and other settings of messages and users. Also, the client application can pull the messages according its options and user settings. These massages are sending email boxes, to devices through the Google cloud or as SMSs.

4 Discussion

The developed solution works as a facilitator to manage the information flows between different types of user groups. Most important sections of the system are its content, and the validity of its content. Since the contents for this system are coming from the ground level and people who voluntarily contribute to the system, the content reflects the ground reality. Since dengue is a larger problem at the ground level, there is a better chance to have decent quality content maintained by its users. The civic engagement is one of the important aspects of the proposed system, which is essential when we need to collect large datasets. By going an extra mile, we hope that this engagement will solve some of the small problem that can be ended by themselves (or as a group), without the help of the authorities. System is also encouraging this by maintaining its content as open-content and by providing necessary functionalities. (Ex: through social ambassadors, forum, content validates etc.).

One of the major challenges of a technology-driven participatory health system enterprise is validating the quality of informational inputs from citizens. Selected content of the system must undergo through a verification and filtering (ex: photos and videos) in order to remove unrelated contents. Our validation process is consistent in keeping with the core idea of using participatory media and crowd sourcing technologies. In that, we use people (individuals and health systems personnel) as validation experts. If users are self disciplined to provide only related information, then the system can avoid this and get rid of the delay and effort that needs to verify the information.

5 Conclusion and Future Work

We have created a middleware platform to enable diverse users to collaborate and contribute multimedia contents for vector-borne diseases and related issues. The usage of familiar input channels (such as Twitter) for contents collection was made an immense improvement in the system. One of the key points that can observe in the systems is that, except for the hotspots, all other content is from end users. So except for administrative operations, the need of a specific assistant required for the system is minimal. The results obtained show the potential benefit in significantly alleviating the burden of laborious user intervention associated with conventional information gathering.

One of the future improvements of the system is to create a better content management system thath will reduce the drawbacks of the current system. The opportunities will consider building a system to prevent users based on various identifications in a misuse of the system. Visualization of twitter feeds are also can be enhanced by using an improved filtering mechanism. Building on an intelligent content analyzing mechanism will also help to have a better understanding on the ground. Another possible future enhancement will be the prediction of hotspot using different parameters. The development of a predictive module will help users to identify danger zones in advance and take the necessary precaution as early as early possible.

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Assessing the Effects of Mobile OS Design on Single-Step Navigation and Task Performance

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Abstract. When working on a task, mobile device users want to complete their work as quickly and efficiently as possible. In order to accomplish this they must use the navigational tools available on the system's interface. The importance of control design to user success requires system designers to consider all aspects of interface design: control tool characteristics, target audience demographics, and even frequency of use, to name a few. This research investigates characteristics (shape, location, and depth vs. breadth) of navigational control tools in order to determine their impact on user performance during common tasks on a mobile device. Cue theory predicts that performance is enhanced when cues are provided during decision-making situations. In the current research, controls with appropriate differentiation are expected to provide the cues necessary for users to more quickly identify their desired target.

Keywords: mobile computing, interface design, navigational control, Cue Theory, Fitt's Law.

1 Introduction

Today's business and personal spaces are seeing an explosive proliferation of mobile devices. According to a recent Gartner report, worldwide smartphone sales reached 149 million units in the fourth quarter of 2011, a 47.3 percent increase from the fourth quarter of 2010 (Gartner 2012). Additionally, Business Insider reported that mobile tablet sales will reach over 450 million units by 2015 and grow at a 50% compound annual growth rate over the next few years due to both falling prices and market penetration in the enterprise and education sectors (Gobry 2012). Ubiquitous computing is becoming a reality around us through the combination of mobile and pervasive computing technologies (Lyytinen and Yoo 2002; Rosenbush et al. 2003). Mobile information technology (IT) services are quickly being adopted at both the personal and organizational levels due to improvements in the data processing capabilities of these mobile devices (Kim et al. 2009). In addition, organizations of all types are seeing the value opportunities of mobility (Barnes and Huff 2003; Clarke III 2001; Yuan and Zhang 2003). As these mobile technologies and services continue to integrate, users are taking advantage of and connecting to them through smaller and

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 383–390, 2013.

smaller mobile devices such as smartphones and tablets to meet their computing needs.

One of the negative implications of this incredible technological sprint is that as the person-machine systems become more complex and sophisticated, the knowledge and information necessary to operate and maximize positive outcomes often exceed human capabilities (Rudolph, 2000). With the established knowledge that both type of information and amount of information conveyed is important to user performance (Dick et al, 2005; Kerr, 1973; and Kantowitz & Sorkin, 1987), user interface designers and developers need to consider user limitations and user abilities when launching mobile systems and applications that will potentially be used by untrained or inexperienced individuals.

In his user activity model, Shneiderman (1982) introduced the world to the term direct-manipulation in the context of interface control. Since that idea was introduced, system and interface designers have embraced the concept and most modern interfaces utilize controls that allow some type of direct-manipulation. With the proliferation of mobile technology this is seen as even more important due to size constraints and portability requirements. Though direct-manipulation is accepted as the standard for interface design (Lim, Benbaset, & Todd, 1996), the characteristics of the controls that are used to manipulate the system are still in dispute due to the complex nature of the problem. To find evidence of this, you need look no further than the various mobile operating systems available in the market today. Most design experts state that differentiation in interface controls is crucial to successful system navigation and user efficiency (Schwartz & Norman, 1986; Nielsen, 1999b, 2000). And while the Android OS uses system specific themes and remains fairly consistent in their color pallets and control sizes/shapes, there are differences in the way they operationalize their OS interfaces across different implementations.

While some corporations are designing applications with similar looking icons, small icons, and even icons that appear in different locations on the screen, several corporate entities are at least following the advice of design experts (Nielsen J., 1999a) and grouping tasks into functional categories and other characteristics that aid users in searching for specific items. One motivation for this study stems from this apparent disagreement. Therefore, in this research we will examine the effect that control characteristics (color, size and location) have on user performance.

Research in HCI has examined control design and layout on keyboards and other user devices such as personal digital assistants (PDA) (Card, Moran, & Newell, 1983; Lim, Benbaset & Todd, 1996; Shneiderman, 1998), but less research has been identified that looks at mobile OS icon design. One reason it is important to study this type of system and this type of user is the recent trend of organizations launching mobile applications that are targeted at untrained users on the move. The systems being launched include shopping portals, payments systems, organization, governmental or business portals, registration and enrollment systems, and even social media and networking systems. The users of the systems identified will have differing levels of platform and device proficiency, market and organizational knowledge, and will have little to no access to any help other than that help functionality inherent in the application itself. With these typical systems and users in mind, this research study also aims to capture user satisfaction and perception of the mobile operating system as well as user performance and their intention to use.

The major research questions of interest:

- How do control characteristics (color differentiation, location, and size) affect user performance in select tasks?
- How do control characteristics (color differentiation, location, and size) affect user attitude?
- How is user attitude affected by user performance?
- How is behavioral intention affected by user performance and attitude?

2 Prior Research

2.1 Target Users and Mobile Operating Systems

The typical users targeted by this research have varying levels of mobile technology experience, varying levels of Internet experience, and varying levels of mobile application experience. The occasional user of the mobile operating systems under investigation (Android based OS) would be without system expertise but would nonetheless be required at times to make use of the system.

Customarily, the type of system under investigation in this research would provide neither formal training nor documentation, and would be limited in its support function. In some cases use of the system is mandatory (e.g. company requirement) and users wouldn't have the option to use an alternative method.

2.2 Target Users and Systems

Cue theory states that individuals gain perception by taking in all broadcasted cues and putting them together as one would do with a puzzle to come up with the desired picture. Some researchers have compared it to the board game of Clue or a murder scene investigation where the investigator pieces together all the clues available at the scene to come up with the perpetrator responsible for the crime (Allard, 2001). Cues are used by individuals to see, feel, smell, taste or hear clues and deduce what they mean and what type of response is appropriate. In this research, cues will be operationalized as the characteristics (color) (Teichner et al, 1977) of navigational icons. It is expected that users will more easily and quickly distinguish between icons and select the appropriate one based on this characteristic.

Differentiation is provided by using colored icons for each treatment. Each control icon on the interface would have a unique color. If the icon is on several different pages or layers of the OS, the same color is used for the icon each time it appears (treatment 2 might vary the color). The cue of color differentiation is expected to allow the user to more quickly distinguish between control icons and select their desired target more quickly.

2.3 Fitts' Law

Fitts' law states that the time to acquire or point to an object is a function of the distance to and the size of the object, that is, as the distance to the target is increased the pointing time increases. This law further states that the smaller the target the longer it takes to point to or acquire it. Performance is determined by (1) accuracy and (2) time to achieve the desired task.

When Fitts' Law is applied to interface design and targeting of control icons the same 2 main factors need to be considered, the target size (how big the icon is) and the distance to the target (where the icon is in relation to the hand position). This research was interested in the effect of target size on user performance while using a mobile smart phone device. The relative size of the target was altered for the 2 treatments to test the effect of size on performance.

3 Research Model

This research will examine the effect of mobile OS design characteristics on mobile device users' performance, attitude, and behavioral intention. Performance is measured by taking the average time for participants to complete each assigned task. The time to complete each assigned task will be summed to arrive at an overall time to determine performance. Performance measures based on total number of control button manipulations were also collected though the time measure is what will be utilized for all analysis and data reporting.

Cue theory incorporates the idea that when cues are present they enable a user to quickly and easily distinguish between options (Allard, 2001). In this research cue

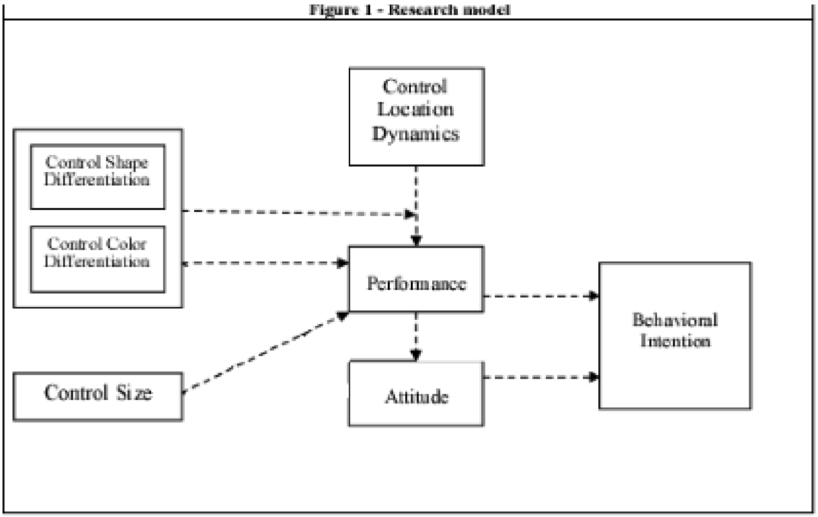

Fig. 1. Research Model

theory has been applied to a search and selection task and it is predicted that performance will be enhanced. Cue theory has been extended to include the concept that learning is enhanced when cues are present (Clibbon, 1995).

Fitts' law is fundamental in offering predictions for performance measures on targeting tasks and has been applied to interface design issues in prior research (Nielsen, 1997; Nielsen, 1998). User performance is a function of both the size of the target and the relative location of the target (Fitts, 1953, 1954). The closer the target to the relative position of the user and the larger the target, the better performance will be (i.e. less time for users to select the desired control button).

- H1: A mobile OS with icons (navigational control) differentiated by color will result in higher user performance than will a mobile OS with consistent colored icons.
- H2: A mobile OS with larger icons will result in higher user performance than will a mobile OS with smaller icons.
- H3: A change in the location of icons (controlled dynamic locations) will result in decreased user performance.
- H4: Color differentiation of icons will reduce the negative effect of control location change on user performance.
- H5: A higher level of user performance will result in an increased level of positive user attitude.
- H6: The more favorable user attitudes towards a mobile OS the higher the level of intention to use the system.
- H7: A mobile OS or application that generates high levels of user performance will result in an increased level of intention to use than will a mobile OS that generates lower levels of user performance.

4 Proposed Method

An experiment is planned using Android mobile devices that are programmed to look like the default factory OS are installed. The experiment will include 4 treatments that manipulate icon color and icon location (2X2). All control button colors for the experiment were selected in accordance with prior research that showed individuals could quickly distinguish one color from another in an interface environment. The colors used for the experiment will include red, blue, yellow, green, black, and white. The study will incorporate a color acuity test to assign any participants who were determined to suffer some degree of color blindness to a treatment where color was not manipulated. The color treatments were assigned to control icons independent of any meaning or purpose of the button. A potential problem could be identified by using colors and assuming that no relationship exists between the color and an inherent meaning attached to it. Colors tend to have prototypical associations attached to them and when an individual sees the color they immediately think of this attached symbol, object or meaning (Helmholtz, H. von, 1925; Rosch, 1975). It might be useful to begin a study with a test that identifies any prototypical meaning attached to the colors used to offer a baseline possible explanation for results observed.

Table 1. Proposed Experimental Design for OS Screen Manipulation

		COLOR	
		Differentiated	Non Differentiated
	Large		
SIZE	Standard		

Control button location will be manipulated as a within subjects treatment. For the first few tasks in the Experiment, the controls will be located in the exact same location on each page where they appear. For the last few tasks the control icons will be rearranged into new locations. The control button size manipulation will be accomplished by using two levels of size: (1) the standard size as developed by the electronic procurement system designers, and (2) a size that is larger in each dimension than the standard.

4.1 Data Capture and Preparation

We plan to include a minimum of 40 participants for this study. Performance will be measured by taking the average time for participants to complete each task. To arrive at this measurement, the total time to complete the assigned list of tasks will be divided by the total tasks completed. Performance measures based on the total number of control icon clicks will also be collected though the time measure, and is what will be utilized for all performance related analysis and data reporting.

Attitudes toward the mobile operating system will be measured by a set of seven 7-point Likert-type questions adapted from Part 3 of the long form of the QUIS (Questionnaire for User Interaction Satisfaction) (Shneiderman, 1998).

4.2 Method of Analysis

For the purposes of this study, assignment of subjects to treatment groups will be random. Randomization will be achieved by assigning the treatments (1-4) in an incremental order to subjects as they walk into the laboratory. Thus, the first four subjects will be assigned treatments 1 through 4 and will form the first set. The assignment will be repeated for the remaining groups of four subjects, so that all individuals form four treatment cells with ten participants in each. The randomization procedure can be checked by analyzing differences in demographic variables among treatment groups such as gender, computer efficacy, and experience. Attitude analysis using Cronbach's alpha will determine reliability. We will also test for the presence of any additional benefit from deleting items from the scale. If not, the attitudes scale will be constructed by averaging all seven items.

General demographic information will be captured but will not be linked to specific participants and will be used in raw data and grouped data analysis only.

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Security, But at What Cost?

An Examination of Security Notifications within a Mobile Application

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Abstract. Research on the behavioral-based security of information systems within organizations and for personal use has been common over the last decade, however little is known regarding how individuals perceive the security of their mobile devices. This study seeks to explore how the security notifications within a mobile application environment alter adoption and security-related beliefs concerning their device. We propose a theoretical model based on the technology adoption and psychological theories, and propose an experiment to test the model. Contributions and implications of the work are then proposed.

Keywords: Mobile device, mobile security, human-computer interaction, mobile application, security notification.

1 Introduction

The adoption of mobile devices continues at an unprecedented rate throughout the world. Some countries even boast an average of more than one mobile device for the entire country. However, despite this widespread adoption of the mobile/smart phone across the world, it is not fraught with difficulties and shortcomings. Only recently has researched begun to focus on the security awareness of users in regards to their devices. Research has shown that users are unaware of the risks that these devices pose to their own personal information. Additionally, these devices provide a host of security-related issues at the organizational level (e.g., policy for device usage of BYOD, government and corporate espionage enabled through mobile connectivity, use of personal devices for organizational functions without adequate monitoring and oversight on such devices). Therefore, mobile devices have become a new target for security attacks, which pose serious threats to the security of such devices [5], to individual users [10], and to organizations when used and transported outside of their physical organizational boundaries [7].

With rapid adoption of mobile technologies, it has achieved pervasive adoption levels as users have mobile devices for both personal and work-related activities. At the

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 391–399, 2013.

individual user level, mobile user experiences are increasingly enriched by various mobile applications customized for different mobile devices. However, mobile applications can be a double-edged sword, which can cause serious security risks and threats to individual users. Research [10] points out that users are not fully aware of the potential damage to their personal assets and private information saved in their mobile devices as they may be conditioned to the process of installing malicious mobile application. It is unclear how much users are aware of their mobile security settings, and how they should take proper actions to effectively protect their assets saved in mobile devices, in that two extreme approaches exist in current user practices: one approach is that users blindly apply existing security solutions that normally applied to desktop platforms to all mobile devices, and the other approach is that users only consider new security techniques for mobile devices. The truth usually lies in-between with some level of justifications in different mobile environments [3], [6], [10], [13].

Many practitioners have started to pay attention to mobile security issues; while current research especially focused on users' mobile security behavior is scant. This paper focuses primarily on the security awareness of mobile users as an initial project to explore how to increase the security of mobile devices through the use of security notifications to increased perceived perceptions of privacy and security. Building on theoretical ideas from community health theories, we propose that individual users must be first made aware of such problems prior to introduction of any solution to this dilemma. Specifically we explore how the usability of the mobile phones interface to display security notifications regarding attempted behaviors on the phone will alter the users' perceptions of security, feelings of irritation, and intentions to continue to use the devices.

In the next section, we briefly introduce theoretical background for this research, and propose a research model to examine how different levels of disruptive security notifications pushed into a mobile smartphone affect user security perceptions of their mobile devices and their intentions to continuous use the mobile application. Then we propose a study design and discuss expected contributions to the field.

2 Theoretical Background

The number of security threats to mobile devices is rapidly increasing, and effectively managing security in mobile environments is a challenge due to (1) mobility and small size of mobile devices despite the constraints in both computational and power capabilities; (2) disadvantages of being incapable of taking advantage of a platform's hardware architecture on the mobile devices; (3) obscurity between platform and network; (4) mobile attacks; and (5) mobile device usability issues [10]. Today's mobile users are exposed to all sorts of complex security services and mechanisms, which can be confusing and ineffective to them to protect their mobile device security. Josang and Sanderud [8] suggest making the security services and mechanisms as transparent as possible to users to ease the process, but can be constrained by users' background and capabilities to handle their mobile devices. Furthermore, they indicate that it is crucial to design mobile security interfaces in an intuitive and intelligent way. Further, users are often completely unaware of any security vulnerabilities in their devices, which is drastically different than their view of computers. While users have a general sense of the potential harms due malware, security vulnerabilities, etc., they have no such belief regarding the vulnerabilities of their mobile devices.

In this research, we focus on mobile usability issues associated with mobile devices to examine users' awareness and ability to respond to various mobile security notifications. We begin by building on the Apple Usability Guidelines[1] and the technology adoption model to propose how the interface of a mobile device impacts users' intentions to continue to use the device. This underlying portion of our model provides a baseline to assess the general usability of a device, and ascertain how that impacts perceptions of security and intentions to use such a device in the future.

Next, we explore how security notifications pushed to the user due to application of device operations may interrupt the cognitive processing of the individual and cause a sense of irritation. This builds upon the work by McCoy et al. [9] by extending their web-based premises and manipulations to the mobile operating system context. We propose that more frequent or disruptive push notifications will cause the user to become irritated with the mobile device. By interrupting the operations of the phone or application and forcing the user to attend to such notifications, the sense of irritation will result in a general sense of dissatisfaction that will negatively impact the ability of a well perceived interface to positively impact intentions to use the device.

However, we propose that such disruptions also have a beneficial purpose. When users engage in a task, they become highly goal focused and are attempting to achieve such goals. By interrupting this process and providing some notification that these goals may conflict with security-related goals, we attempt to show that current goal-directed behaviors may in fact not be desired when considered by concurrent yet differing security-related goals. Thus, such notifications, although detrimental to the operations and usefulness of the phone, may improve perceptions of security for the phone.

Our proposed research model is summarized in Figure 1, which we now briefly propose.

The initial hypotheses are an extension of the Technology Adoption Model [4] to mobile devices, which has been previously validated [2]. As the users' main interactions with a mobile device are based on the graphical interface of the device, it becomes the predominant antecedent of the ease-of-use for the device. We thus replicate prior research and propose:

> *H1: The mobile device user interface will be positively related to the perceived usefulness and ease-of-use of the device.*
>
> *H2: The perceived usefulness / ease-of-use of the mobile device will be positively related to the intention to continue to use the device.*

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[1] `http://developer.apple.com/library/mac/#documentation/userexperience/conceptual/applehiguidelines/UEGuidelines/UEGuidelines.html`

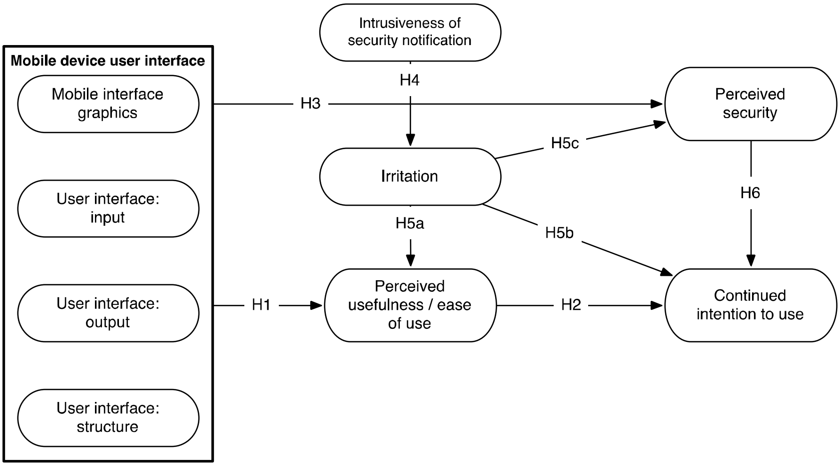

Fig. 1. Theoretical Model

Unlike computer operating systems and environments, mobile devices do not have built in security applications that provide dashboards regarding the relative security of the device. Rather, users are notified regarding any changes or requests by applications relative to private or secure information through the means of notifications. How these notifications are delivered to the user is determined by the interface of the mobile device. We thus posit that the awareness of the device's mobile security is primarily engendered through such notifications as afforded through the interface of the mobile device.

This is an extension from prior research on information system quality. Previous work has both proposed and found that systems that are perceived to be of higher interface design as perceived as being of higher quality [2]. We further extend this finding by proposing that higher quality systems, by being perceived in a more favorable view, are likewise perceived as more secure. This is in alignment with the cognitive psychological theory of attitude consistency, which emphasizes that individuals tend to align beliefs of the same attitude objects in order to avoid inconsistency [12]. Thus, users of the mobile device, believing it to be of superior quality will infer that its other attributes are also likely to be of equally high quality, even without any direct source of information to corroborate this belief [1].

H3: Devices that are perceived as having superior user interfaces will be positively related to higher perceptions of mobile device security.

We propose that within application notifications are similar to pop-up and in-line ads present on the websites. We thus extend the work of McCoy et al. [9] that when such notifications are perceived to be more repetitive will have the potential of being perceived as being more intrusive. Constant repetition of the same information, or same type of notification is likely to disrupt the cognitive flow of information that an individual requires when focusing on a task. This disruption will likely be perceived as an intrusive force, that disrupts the use of the current application. Following this, we pose that as the notification is perceived as being intrusive, it will lead to feelings of irritation by the user [9]. We thus extend this prior line of reasoning and research to the context of mobile security notifications and propose:

H4: The perceived intrusiveness of notifications will be positively related to the perceived irritation afforded by such notifications.

Building on psychological theories of attitude change, we pose that as negative emotions regarding the mobile device are increased, that intentions or perceptions regarding the device will also be negatively impacted [11]. Specifically, as the user becomes irritated with the security notifications, it is likely that these feelings will negatively impact the perceptions of the ease-of-use and usefulness of the device, which will negatively impact the intention of the user to continue to use the device. However, the engenderment of irritation will potentially positively impact perceptions of security. Irritation will likely raise the salience of cues regarding the security of the device, and provide the user with a sense of control over their data and their device, and thus increase the perceptions of security. We thus propose that feelings of irritation caused by the security notifications will produce the following outcomes:

H5a: Feelings of irritation caused by the security notifications will negatively impact the perceptions of usefulness and ease-of-use of the mobile device.

H5b: Feelings of irritation caused by the security notifications will negatively impact the intention to continue to use the mobile device.

H5c: Feelings of irritation caused by the security notifications will positively impact perceptions of security of the mobile device.

Finally, although practitioners have long proposed that security is at odds with the general day-to-day usage of an application, we formally test this assumption. Specifically, we pose that when users feel that a device is more secure they will have even more intentions to continue to use the device, as a potential negative future event (e.g., a data breach) would likely not occur. Thus, we propose:

H6: As the perceived security of the mobile device increases that the user will have greater intentions to continue to use the device.

3 Proposed Study Design

We intend to assess the accuracy of our theoretical model through the means of a 2 (high vs. low threatening conditions) x 3 (highly disruptive, moderately disruptive and no notifications treatment groups) randomized experiment with mobile phones. In the highly disruptive treatment condition, users would be exposed to push notifications during the process of the experiment that alerts them to security violations. The user would be unable to perform any other task until they first read through the entire violation and then approve or disapprove of such an action. They would then be returned to the screen that they had been using.

In the moderate disruptive notification, the user would receive a push notification that is minimally inserted into their view, but does not obstruct or interfere with the tasks that the user is currently working on. Rather it would simply notify of the violation, and not require any interaction on the part of the user.

In the no disruption condition, we would allow the user to complete tasks as specified by the experiment, and they would never receive any notification of any security violation. This would serve as the control condition to ascertain how much variation in our model is simply caused by the notification process.

Currently, we have designed and implemented a mobile security notification system that can be run in various mobile phones. We plan to recruit users from several US university campuses in Spring 2013. The incentive will be extra points for participating in our study. We also designed two different scenarios for this experiment: one is a hedonic environment (i.e., a mobile game), and the other one is a non-hedonic environment (i.e., a Wikipedia article on "computers"). In both scenarios, users will be exposed to different levels of security notifications (see Figures A1 and A2). At the beginning, users will be instructed by researchers regarding the experiment, and then users will be randomly assigned to one of the ten treatment groups (2—high vs. low threat— x 2—highly vs. moderately disruptive— x 2—hedonic vs. utilitarian conditions, with one hedonic and one utilitarian control group). The whole experiment will take users about 15-20 minutes. After they complete the experiment using a mobile smartphone, they will be asked to fill out a questionnaire that assesses common demographic controls and items to assess the constructs of interest in this study. Screenshots for these treatment groups are shown in Appendix 1.

4 Expected Study Contributions

This study would have several important contributions for research and practice. First, by examining how the user perceives highly and moderately disruptive notifications, we would be able to offer practical guidelines for practice as to how to notify users about security violations. Given the predominance of these two types of notifications, this has strong practically implications regarding whether security-related notifications should be reported with one or both types of notifications. Further, given potential future results of this study, we could explore whether the type of notification interacts with the degree of threat being broadcast via the notification. It is possible that the level of threat may fit with a specific type of notification. For example, highly threatening notifications may produce better outcomes if it is notified with a highly disruptive means, while low threatening notifications should be broadcast with moderate disruptions. We would explore this potential fit condition.

Thus work would also validate our theory in that the disruptive effect of notifications serves to increase perceptions of security by the user, this is a novel notion. Currently, with the scant amount of mobile security research that has been published, no research to date has reported any antecedents that increase the perceptions of security afforded by a mobile device. This would be the first such study to begin this important process by showing a process whereby security notifications are able to improve the perceived security of the device, while likewise decreasing the perceived usability and ease-of-use of the device.

Another important contribution that this work would provide is the inherent tradeoff between the usability of an application and its perceived security. This is a topic that is commonly discussed within practitioners of security, but has yet to be validated in any meaningful or empirical way. This would provide the first real empirical validation of this assumption. By showing whether this assumption is valid or not, this research could initiate the first steps towards identifying antecedents that may potentially increase the perceived security of a device while likewise increasing the perceived usefulness and ease-of-use of the device.

5 Conclusion

Mobile devices are becoming a way of life around the globe. While the development of more applications, and the adoption by more users increases the incentives for users to also adopt, there is little research exploring how users can be made aware of the potential security issues and problems inherent in such devices. Whereas most users are aware of virus, malware and other such dangerous software on their personal computers and laptops, very few are aware of similar threats on their mobile devices.

This is an initial study that proposes an adoption-based theoretical model to explore how the interface notifications impact the perceptions of security, and the intention to continue to use the device. We propose a laboratory experiment, using mobile device users on their own devices, in which they are exposed to differing levels of security-related notifications and varying levels of security-related threats. We propose to analyze the results of such a study and explore potential fit conditions between the type of notification and the type of threat being communicated. Further, we would test the theoretical veracity of our model.

We propose several important contributions for research in practice, with the most important being a call to focus on mobile-based security research. This area of security in regards to information technology is lacking, which is an appalling condition given the lack of awareness that exists in the general populace. We also note that this would be the first study to explore how the interface of the mobile device is able to impact perceptions of security, and likewise how the perceptions of security on the device impact the user's intention to continue to use the device.

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Appendix

Screenshots from the experimental website.

Control Group—
No disruptions | Highly disruptive | Moderately disruptive

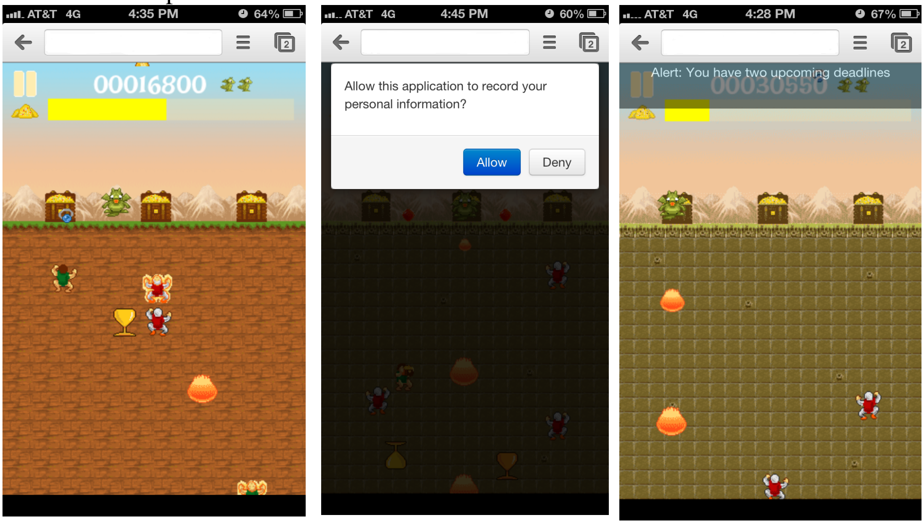

Fig. A1. Hedonic Scenario Mobile Smartphone Experiment Interfaces

Control Group—
No disruptions | Highly disruptive | Moderately disruptive

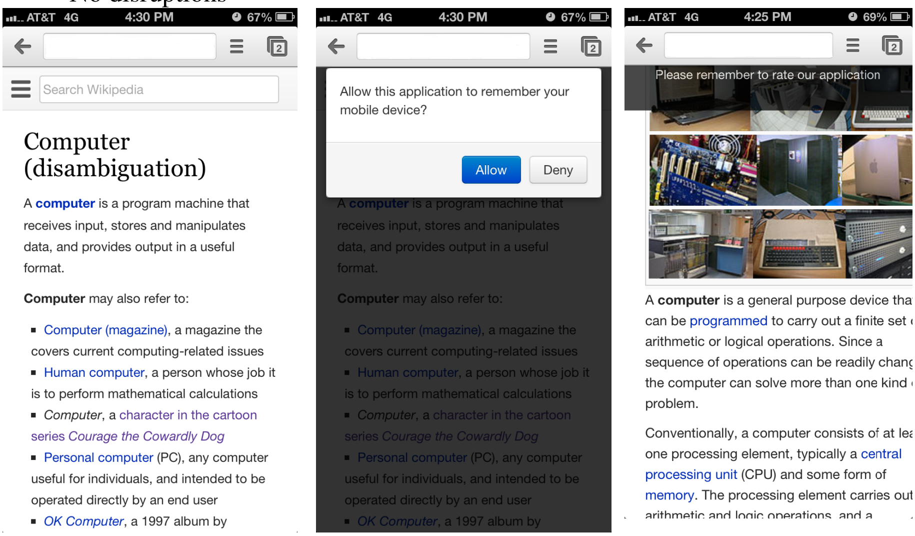

Fig. A2. Non-Hedonic Scenario Mobile Smartphone Experiment Interfaces

Tactile Vibration of Personal Digital Assistants for Conveying Feelings

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Abstract. At present, there are very few methods to utilize the vibration function in personal digital assistant (PDA) devices, which are simple, but poor in variation. These methods do not effectively use the vibration function's potential. In our research, we aim to maximize the use of vibration function for communication using PDA devices with the objective of adding a new value to the PDA's vibration function. We evaluate the relationships between vibrations and images evoked by them. From the results, we found the vibration patterns corresponding to each eight main type of feeling words in Japanese.

Keywords: Tactile vibration, PDA (personal digital assistant), communication.

1 Introduction

The vibrate function is regarded as among the most useful functions of personal digital assistant (PDA) devices, which incorporates numerous sophisticated functions. This function alerts users about an incoming e-mail or call, doing so either with or instead of ringing. In noisy public spaces such as trains and in places requiring quiet such as meetings and hospitals, this function is absolutely essential. Thus, almost all cell phones in the market have a vibration function.

On the other hand, the development of applications for PDA devices is gaining tremendous momentum. In particular, instant messenger for real-time communication is allowing richer communication of emotions by enabling users to send or receive pictographs and stamps with text.

Fukui (Fukui et al., 2011) [1] researched the function of a touchscreen propagating a vibration to the fingertip when it touches the screen, and experimentally demonstrated that specific vibration patterns provide images corresponding to them, especially images about operating devices. From this finding, we deduce that the vibration function might be a new mode of communicating feelings; for example, a PDA device can receive specific vibration patterns corresponding to the content or meaning of a text when a user is holding it in his or her hand or in a pocket of clothing.

Therefore, in this research, we investigate the feasibility of using the vibration function to send and receive vibration patterns corresponding to messages, thus enriching communication using PDA devices. In particular, in this paper, as a first

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 400–410, 2013.

step, we suppose a situation in which a user has a cell phone in his or her hand, and aim to demonstrate experimentally the relationships between vibration patterns of a device and various feelings.

2 Method

2.1 Experimental System

Outline of the Experimental Device. We designed and built an experimental device to generate a variety of vibration patterns in the examinee's hand via a micro vibration motor implanted in a housing simulating a smartphone (Figs. 1 and 2). Figure 3 shows the circuit diagram of the housing.

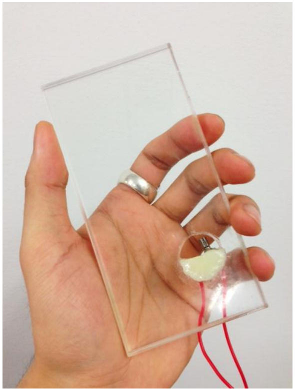


Fig. 1. Housing simulating a smartphone

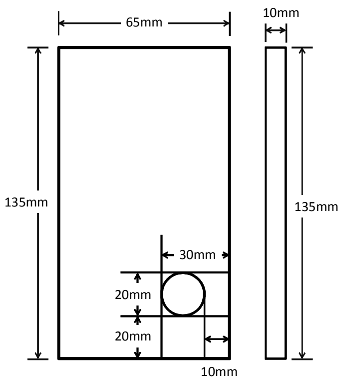


Fig. 2. Size of the housing

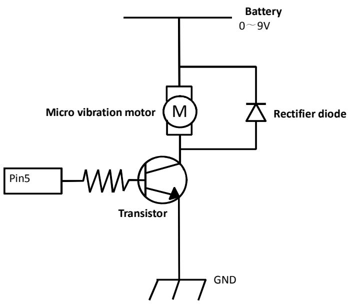


Fig. 3. Circuit diagram

The microcontroller (Arduino) is controlled by programs written in processing, and the micro vibration motor is driven by an electric current between 26 and 126 mA per 1.0 ms flowing from the circuit containing the microcontroller.

Preliminary Experiment to Decide the Vibration Patterns. To help us decide the vibration patterns to be presented to the examinees, we performed a preliminary experiment. Our objective was to demonstrate the relation between psychological and physical quantities of vibration intensity generated by the housing. An examinee sat in a chair and held the housing in his hand, similar to a smartphone (Fig. 1). All vibration waveforms were rectangular, as shown in Fig. 4, and they differed only in amplitude. The amplitude depended on the strength of the electric current flowing through the motor. In this preliminary experiment, we decided to present vibrations generated by the following eight values of electric current to the examinees: 26, 40, 54, 69, 83, 97, 112, and 126 mA. We presented two different vibrations as a pair to the examinees, who then scored how much stronger (or weaker) the first was than the second on a scale of −100 to +100. Each examinee did a comparative evaluation of all pairs (8 × 7 = 56 pairs). The order of vibration pair presentation was random. The examinees were 20 healthy university students between the age of 21 and 24 years (19 male, 1 female).

For all vibration pairs, we calculated the average values of the scores by the examinees and analyzed using Scheffe's paired comparison. As a result, we obtained relative values of psychological quantity about the intensity of each vibration, as shown in Fig. 5. From this result, the relation between psychological and physical quantities of vibration intensity is shown in Fig. 6. In Fig. 6, the horizontal axis indicates the quantity of electric current defining the intensity of vibration, and the vertical axis indicates the relative intensity of vibration calculated by Scheffe's paired comparison with the scores given by the examinees to each vibration pattern. The relation shows a curved line, which can be explained by the Weber–Fechner law, and indicates that the intensity of vibrations the examinees felt was not directly proportional to its physical quantity. In other words, a gap of intensity between two arbitrary vibrations is felt differently owing to the intensity of the vibrations themselves.

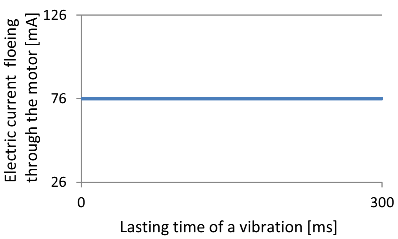


Fig. 4. Wave form of vibration for preliminary experiment

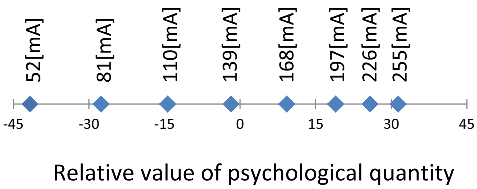


Fig. 5. Relative values of psychological quantity about the intensity of each vibration

Vibration Patterns to be Presented to the Examinees. To set up the intensity of vibrations to be presented to the examinees conforming correctly to the psychological quantity, we adopted conversion formulae for the electric current, as shown in Table 1, on the basis of the results of the preliminary experiment. These formulas convert relative intensity of vibration to electric current which flow through the motor. In Table 1, X means the relative intensity, and Y means electric current.

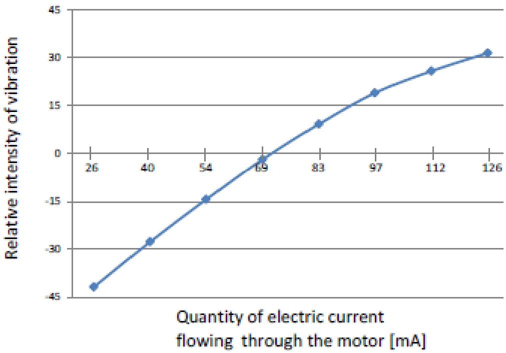


Fig. 6. Relation between psychological quantity and physical quantity of vibrations' intensity

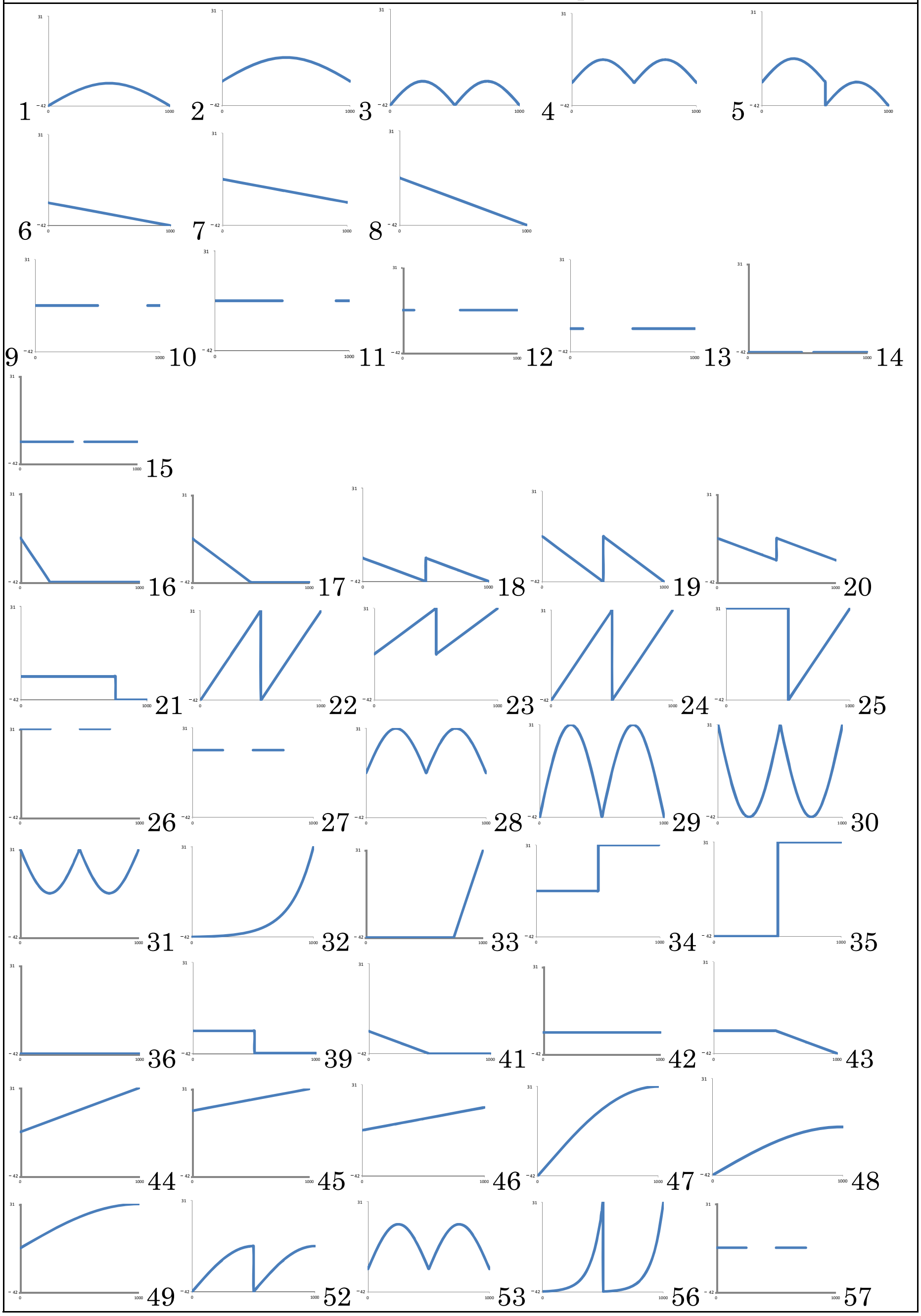
Table 1. Conversion formulae for the electric current to implement the intensity of vibration conforming to the psychological quantity

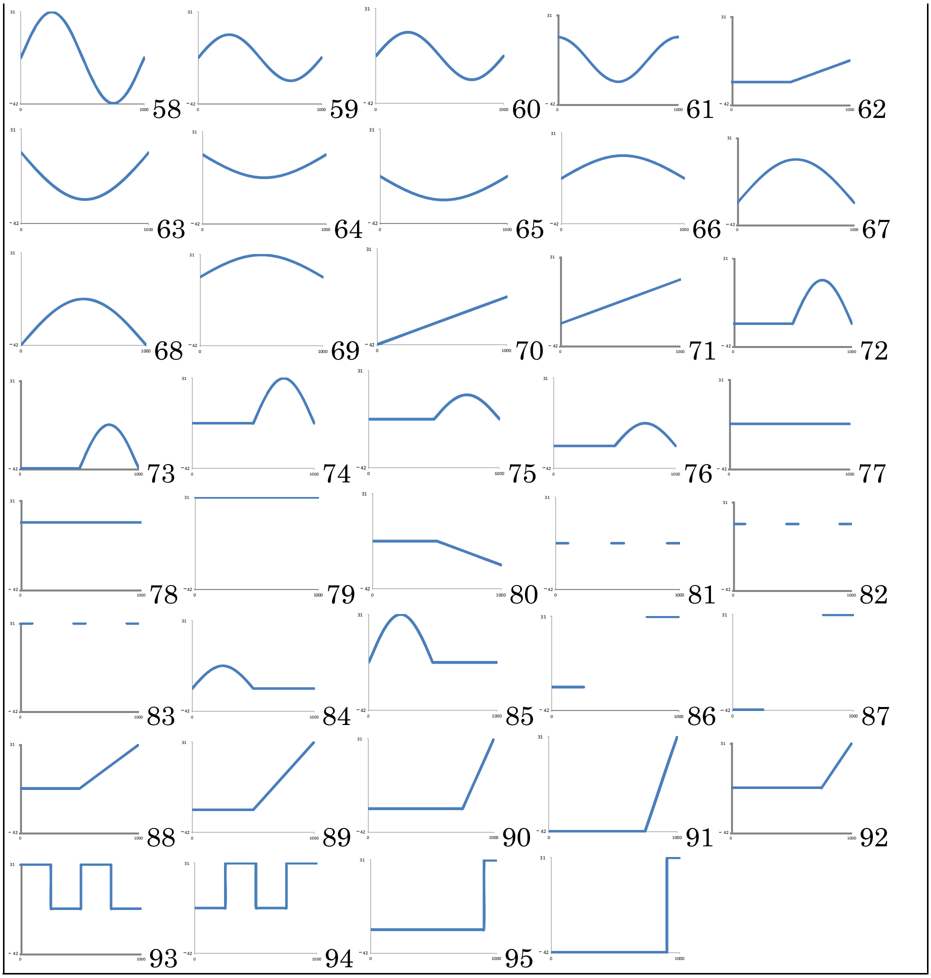
Range of vibration's Relative intensity	Conversion formula
-42≦X<-28	Y=1.0X-68.1
-28≦X<-14	Y=1.1X-69.9
-14≦X<-2	Y=1.1X-70.7
-2≦X<9	Y=1.3X+71.0
9≦X<19	Y=1.5X+69.4
19≦X<26	Y=2.1X+57.4
26≦X≦31	Y=2.6X+45.8

In the following experiment, we set the duration of one vibration pattern to be presented to the examinees at 1000 ms. Setting the maximum current at 126 mA corresponding to the maximum amplitude and the minimum current as 26 mA corresponding to the minimum amplitude, we implemented vibration patterns with different waveforms generated by varying the current value per 1 ms. We arranged 88 patterns of vibration to be presented to the examinees, as shown in Table 2.

Table 2. Wave forms of 88 vibration patterns used in the experiment

Wave forms of 88 vibration patterns





2.2 Experimental Task

The examinees sat on chairs in the usual position and held the housing in their right hand. We then had them elevate their right elbows above the desk so they could feel the vibration directly in their hand. After administering 88 patterns of vibrations in random order, the examinees scored how strongly the vibrations evoked each emotion or sensation on a scale of 0 to 6 (measurements are shown in the next section). We allowed the examinees to experience one vibration pattern as many times as necessary.

2.3 Measurements

In communication using PDA devices, users convey a variety of feelings. Therefore, to research the relationship between feelings and vibrations, we chose the Multiple Mood Scale (MMS) contracted version [2], a word list that summarized typical feelings of young people. The MMS contracted version is a word list elucidating eight types of emotions (depression and anxiety, hostility, boredom, active pleasure, inactive pleasure, affection, concentration, and surprise) from hundreds of Japanese words describing feelings, which the Japanese male and female university students ordinarily feel by four trials of investigations and factor analyses; we summarized five words having high loading about each factor into a 40 word list. Table 3 shows the 40 words used for the measurements. In the experiment, as described in the previous section, after experiencing 88 patterns of vibrations in random order, the examinees scored how strongly the vibrations evoked images of each of the 40 words on a scale of 0 to 6.

Table 3. Measurements

Factors	Measurements				
Depression and anxiety	uneasy	fraught	caring	diffident	worrying
Hostility	hostile	hating	blaming	aggressive	offended
Bordeom	languid	tired	unexciting	humdrum	languid
Active pleasure	lively	energetic	active	resilient	cheerful
Inactive pleasre	calm	ingenuous	slow	pastoral	casual
Affection	dear	beloved	favorite	charming	lovely
Concentration	attentive	careful	polite	cautious	judicious
Surprise	surprised	amazed	frightened	disturbed	startled

2.4 Participants

The examinees were 21 healthy university students between the age of 20 and 24 years (13 male, 8 female).

2.5 Ethics

Before the start of this experiment, we explained its purpose and contents to the examinees and obtained their agreement in writing.

3 Results

To research the relation between each word and vibration, we calculated the average of each word's score according to the strength of the image the word evoked. For example, Fig. 7 shows the average score of each vibration as the strength of the image of the word "uneasy." We performed a one-way analysis of variance for each word, and as a result, all words have a characteristic effect for a type of vibration.

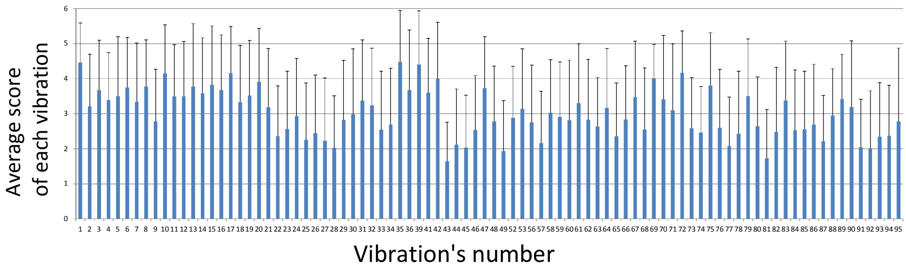


Fig. 7. Average score of each vibration as the strength of "uneasy" word's image

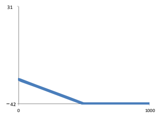
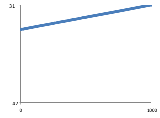
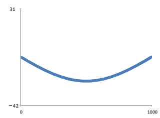
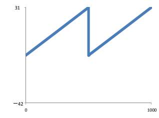
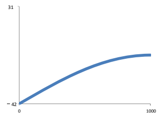
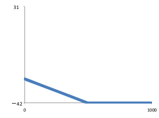
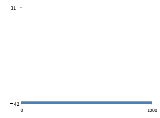
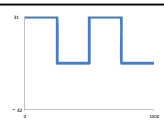
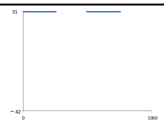
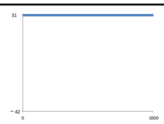
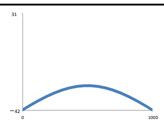
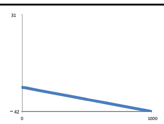
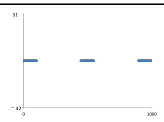
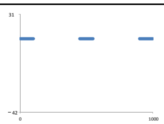
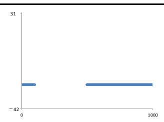
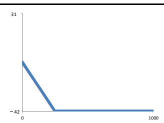
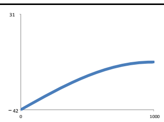
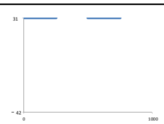
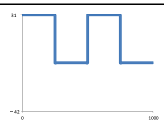
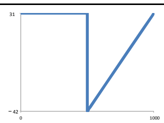
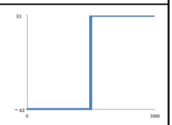
Table 4. The vibration patterns having strong image of each measurement words

Factors	Measurements	vibration patterns	Factors	Measurements	vibration patterns
Depression and anxiety	uneasy	35, 1, 39, 72, 17	Inactive pleasure	calm	42, 6, 1, 83, 15
	fraught	35, 39, 15, 13, 6		ingenuous	39, 20, 35, 83, 1
	caring	12, 90, 18, 58, 72		slow	35, 42, 6, 1, 15
	diffident	39, 36, 12, 17, 35		pastoral	42, 6, 35, 1, 83
	worrying	35, 13, 15, 39, 42		casual	6, 7, 47, 1, 2
Hostility	hostile	84, 44, 22, 92, 24	Affection	dear	59,
	hating	64, 15, 1, 13, 3,		beloved	81, 74, 80, 26
	blaming	64, 35, 47, 20, 16		favorite	81, 80, 33, 28, 25
	aggressive	44, 22, 84, 27, 92		charming	81, 30, 80
	offended	13, 61, 36, 41, 47		lovely	33, 59, 28, 80, 93
Boredom	languid	13, 39, 15, 35, 42	Concentration	attentive	47, 14, 18, 6, 2
	tired	39, 6, 16, 1, 13		careful	15, 79, 39, 12, 35
	unexciting	39, 15, 35, 17, 13		polite	15, 79, 47, 67, 35
	humdrum	35, 15, 42, 39, 36		cautious	72, 14, 1, 12, 18
	languid	35, 13, 6, 17, 39		judicious	12, 3, 42, 15, 47
Active pleasure	lively	78, 93, 82, 92, 44	Surprise	surprised	78, 84, 25, 92, 34
	energetic	92, 24, 25, 44, 78		amazed	25, 92, 34, 78, 24
	active	78, 44, 27, 25, 92		frightened	25, 92, 24, 59, 86
	resilient	92, 82, 22, 78, 25		disturbed	34, 86, 84, 90, 93
	cheerful	82, 92, 22, 84, 25		started	25, 24, 92, 85, 34

Consequently, for those vibrations having especially the images of these words, we extracted the vibration patterns with an average score of 3.5 and above, or patterns having scores ranked in the top five of all vibrations. The results are summarized in Table 4.

According to these results, it was indicated that the words belonging to the same factor (shown in Table 4) have a strong relation to comparatively similar vibrations. For example, the words "energetic" and "active" belong to the same factor, and both words have strong relation to vibration pattern no. 92 and 82. Subsequently, we focused on the vibration patterns having a strong relation to each factor and summarized them in Table 5. First, in the group of the factor "depression and anxiety," the vibration patterns having small amplitude and little varying waveforms were extracted. This indicates that the vibration patterns having small amplitude and waveforms that vary little can be used to convey the feeling of this factor suitably. Similar to this, in the group of the factor "hostility," the vibration patterns had waveforms rising near the end; in the group of the factor "boredom," the vibration patterns were extremely similar to that of "depression and anxiety"; in the group of the factor "active pleasure," the vibration patterns had large amplitude and waveforms with repetition of form or rising trend; in the group of "inactive pleasure," the vibration patterns had waveforms falling near the end; in the group of the factor "affection," the vibration patterns had waveforms with average intensity and discrete form; in the group of the factor "concentration," the vibration patterns had small and almost constant intensity and waveforms with a simple variation, like a very short break; in the group of the factor "surprise," the vibration patterns had very large amplitude; and waveforms with breaks or a reputation of up and down were found to be the vibration pattern common to each factor.

Table 5. Vibration patterns having strong relation to each factor

Factors	Vibration patterns common to common to a factor			
Depression and anxiety (uneasy, fraught, caring, diffident, worrying)	35 	39 		
Hostility (hostile, hating, blaming, aggressive, offended)	44 	64 	22 	47 
Boredom (languid, tired, unexciting, humdrum, languid)	39 	35 		
Active pleasure (lively, energetic, active, resilient, cheerful)	92 	25 	78 	
Inactive pleasure (calm, ingenuous, slow, pastoral, casual)	1 	6 		
Affection (endeared, beloved, favorite, charming, lovely)	80 	81 		
Concentration (attentive, careful, polite, cautious, judicious)	12 	15 	47 	
Surprise (surprised, amazed, frightened, disturbed, startled)	25 	92 	24 	34 

4 Application

It was clear from the results that vibrations presented to users through a housing simulating as a PDA device can evoke images of specific feelings depending on the features of those vibrations. We can propose a new method to apply this result concretely to communication using PDA devices. The first method is a function that attaches the vibration patterns selected by users to messages such as pictographs or stamps in existing applications for communication. The groupings of the vibration patterns depending on the meanings of words, shown in the previous section, will be a great help for users to select the vibration patterns corresponding to the images of their message contents. The second method is a function for attaching the vibration patterns to SNS (Social Network Service) articles corresponding to the contents and providing vibrations to the readers of the articles with text and photos. Doing this may result in more enjoyable applications, enabling us to communicate feelings more richly.

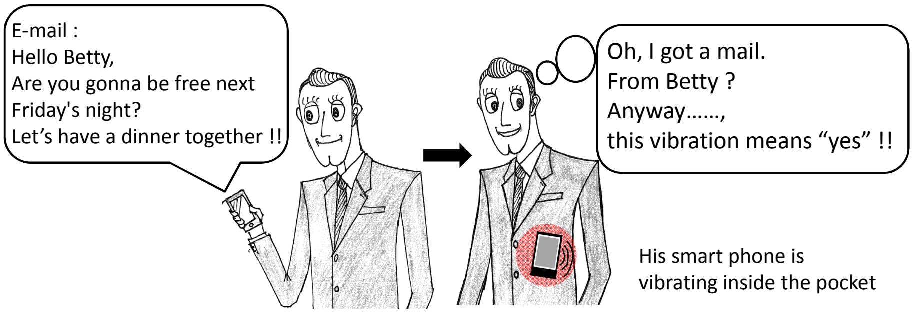


Fig. 8. The image of actualized system

5 Conclusion

In this research, as an idea to enrich communication using PDA devices, we aimed to actualize a function for sending and receiving vibrations corresponding to the contents of messages, and researched experimentally the possibility of doing so. From the result of our experiments, it was clear that there are definite relationships between the vibration patterns and feelings evoked by them, when users experience vibrations provided by PDA devices in their hands. In particular, it was found out that differences in size of the vibration amplitude, existence of variation in the waveforms, and whether the waveforms were continuous or discrete affected which image the vibration evoked.

On the other hand, it can be said that we require additional experimentation to clarify by what factor a vibration's physical quantity evokes certain images of feelings. On the basis of these researches, we will actualize an application for PDA devices for the effective use of the vibration function.

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A New Presence Display System Using Physical Interface Running on IP-Phones

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Abstract. In this paper, we describe our developed a new presence display system running on IP-phone. And we also describe the knowledge provided by construction and use of the before system. We thought that we run new presence display system on touch panel display of IP-phone, then we designed and constructed the new system. Our new system is operating since 2010. People's presence status can be viewed through the web browser such as running on iPad. Presence status on web browser is changed immediately when you change it on an IP-phone. These are used Ajax technology. The presence display is easily customizable in every section. We added the indication of the call state of the telephone to a presence display. Thus you can go to meet a person by the timing when a call was over.

Keywords: Presence display system, IP-phone, touch panel system, network utilization.

1 Introduction

In a office, there is a main phone number, and the transfer of the telephone is performed. In addition, the slight meeting with the person whom a seat left happens quite often. In the case of these, it is convenient when you know whether they sit down in their seat. If all the members are in one floor, you can look around the whole. Because a members are divided into some floors and branches as an organization spreads, you cannot look around the whole. And you cannot know whether the boss talks on the telephone from the outside of the room, because the boss has a private room. It is convenient when you know whether they sit down in their seat and what they are doing. The conventional products were able to display presence, but it is not main function of these products. Therefore a procedure to use presence for was complicated, and the presence was not used.

In our university, we used a classical presence system which use electric bulbs and switches for governors. Using electric bulbs and switches are very simple and intuitive. When turn on a switch, an electric bulb that is located far area shines. However, it was necessary to wire switches and the electric bulbs when seat arrangement was changed, and people increased. And it is difficult to connect a

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 411–420, 2013.

switch and an electric bulb if buildings are different. Therefore we made exclusive hardware using a network and we made a presence system using these devices. This presence system was operated in about 6-7 years, but this system had some problems. Thus we developed new presence display system. In this paper, we describe problems about old presence system and development of new system.

2 Existing Products for Presence Displaying

There are some products displaying presence. Many of presence displaying functions were incorporated in groupware and messenger software[1–5], these function display his/her presence (sitting his/her seat or leaving). There is the system displaying a state of the IP phone[6, 7]. It is necessary to use a PC for changing a presence status, because a system uses agent program running on a PC or a system requires login. When you do not use a PC, it is necessary to start a PC to change presence, and it is very troublesome. WIP5000 (made by Hictachi-Cable Ltd.) wireless IP phone has presence function, the operating menu was very complicated. Therefore we tried this product, but did not installed it.

3 Our Old Constructed and Operated Presence System

Because there was no easily usable existing product, we built a new system. Figure 1 shows a constitution of the system which we built. We made a presence client box connected to LAN to be able to easily operate it like a system using electric bulbs and switches. We arranged a button and LED for four status (in a seat, leaving, in meeting, came home) on this box.

A power supply and a network cable were connected to the presence client box at first, but these cable were obstructive, then we supply +5V power to the box through unused wires in network cable.

A server polls and get the status of a presence client box every 30 seconds. A web page that has presence status list was generated by these information in a server. A user views this web page which page is reloaded automatically by refresh of meta tag in HTML.

When a system was introduced, a button of the status change tended to be forgotten to push it. We made the structure which changed status using an infrared sensor as well as a button automatically. But the infrared sensor was not able to detect a person by a position to put a box on the desk. In addition, the sensor recognized that there was not a person when a person did not move and waited. Therefore, we decided not to use the infrared sensor because a user was confused when status automatically changed by a sensor

Because there were many people who forgot to push the button at the time of return, the system changed status in "came home" automatically early in the morning.

As for the system, five years passed since introduction, and trouble of the hardware or the disappearance of the contents of the flash memory have begun

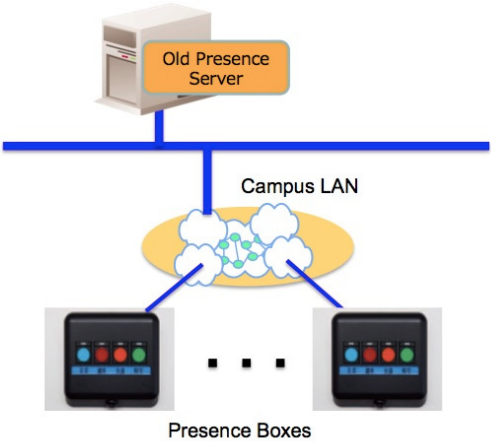

Fig. 1. Old presence display system

to often happen. The hardware supported only 10BaseT, and there was not the power supply by the PoE conformity, too. We did not make the same thing and it was necessary to make a new hardware. Thus we design and construct a new system.

4 Requirements of a New System

A lot of PCs come to be used than before, but do not use the PC by all duties. Therefore, there is the person who does not get the feel of using PC. For them, it is difficult to use a presence function of the groupware. Thus a system using a physical button is necessary. It is necessary that the system can see the list of the presence state from a Web browser like a former system, and real time update is desirable. When we think about installing more equipment, it is desirable that a hardware is a general product. If it is a general product, we can look for a replacement at the time of trouble. Because it is put on a desk, the hardware is small, and it is desirable to support PoE.

We managed a former system, and an opinion was sometimes sent. Though there is not it because a person forgot to push the switch, the indication that is in a state becomes "in a seat". Because a person is talking on the telephone even if the indication that is in a state becomes "in a seat", there is not a talk. It is an opinion to want you to do it to solve these situation. In addition, there was the opinion that these problems might solve if you could go to meet by the timing when a call was over. A call state should be seen in this method.

The general matter of a new presence display system is as follows.

(1) Can put the presence box on a desk.
(2) Operation being simple.
(3) A presence box is a physical box, and a state can transmit a message even if I do not use a PC.
(4) The list of status is seen through Web browser.
(5) The system supports LAN.
(6) A presence box is a general product.
(7) The presence box supports PoE.
(8) The system can check the state of the telephone.
(9) The system does not perform the automatic change of the presence to avoid the confusion of the user besides periodical reset.

5 Construction of a Presence Display System Using IP-Phones

5.1 Review of IP-Phone and Connecting Presence Display System and IP-Phones

We decided to build a new system. Because it was necessary to confirm the status of the telephone from the outside, we decided to perform the update of the business phone which became old at the same time.

The top of the desk becomes small when you put a telephone and a presence box on a desk. Because there was a screen with the touch panel on IP-phone, we thought about whether there was not a presence box using this.

The connection of IP-Phone server and presence display system server is necessary to get the state of the IP-phone (fig. 2). The IP-phone server (IP-PBX) performs call control. The presence display server does management of the presence status and the indication to a Web client. In addition, the presence display server displays a presence button to a screen of the IP-phone and acquires presence status and phone status.

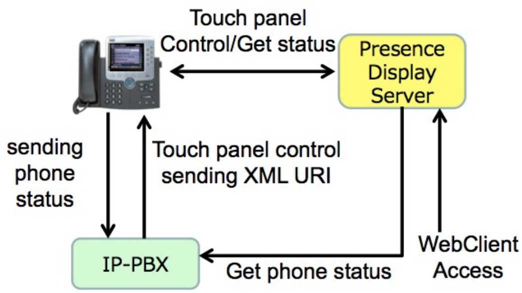

Fig. 2. Relation of server and IP-Phone (at design)

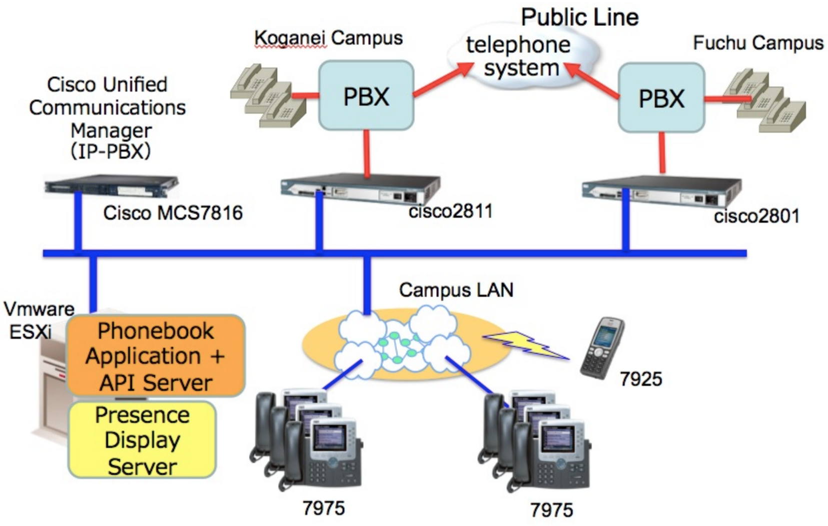

Fig. 3. New presence display system

5.2 Integration of Presence Box in Equipment of IP-Phone

5.2.1 Choice of IP-phone Hardware

We decided to use IP-phone made by Cisco Systems Inc., because that equipment has a touch panel screen. We operate a presence box on IP-phone by improving a telephone book application[8] made by PhoneAppli Inc.. Because this company showed API of the application to us, we were able to develop a presence display system.

5.2.2 Cooperation between Servers and the Forced Change of the Presence State

Figure 3 shows the constitution of the system which we built this time. The IP-PBX server is CUCM(Cisco Unified Communications Manager) which is running on Cisco MCS7816 hardware. This server manages connection of traditional PBX in our university, call control of IP-phones, setting information and the state of the IP-pnone.

On IP-PBX server, we can set URI of XML for the control of the touch panel screen on IP-phone. Because we use the above mentioned telephone book application by this construction, we set a server operating the application at URI. This application server transmits XML data for control to IP-phone and performs screen control in the touch panel.

We wanted to constitute this system like figure 2, but equipment that we used for construction was able to read the status of IP-phone from only one server. Because a telephone book application server uses the status of the telephone,

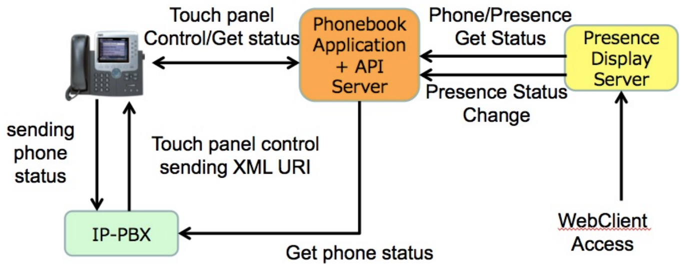

Fig. 4. Relation of server and IP-Phone (at construction)

the status of the telephone is not available from other servers. Therefore, it was decided that the presence server read IP-phone status from this application server (figure 4).

The presence server accesses the inside database of this application server and performs reading and the renewal of presence data displayed on a screen on the IP telephone. When you reset a presence state at the appointed hour, you should renew a database in the application server.

5.2.3 Inidication on a Touch Panel Screen

Figure 5 shows indication in the touch panel of the IP-phone. We can make some button on the touch panel screen. However, the area of the button shrinks if the number of buttons increases. On the basis of easiness of push and an old system having been four buttons, we arranged the button which expressed five kinds of presence states on a screen. The telephone book application that became the base is available when you choose "6. telephone books" of the lower right of the screen. We arranged 3D-like buttons on the screen. In addition, it became hollow and showed the chosen button to understand which was chosen. Other than the operation in the touch panel, you can change an a presence state even if I push the number button of the IP-phone. That both the push button and the touch panel were usable was explained for a user, but understood that users used the touch panel well as a result of our observation. When the response of the touch panel was bad, and a user had a luggage and wore gloves, a push button was pushed.

5.2.4 Get Presence State and Indicate on IP-Phone

A presence state chosen on IP-phone is acquired on a telephone book application server. A presence server checks the change of the database in the application server regularly and acquires a presence state. The presence server generates a log that contained the time when a presence state was changed.

When the IP-phone is shut down and reboots, states of the menus are usually reset. When the user does not notice that IP-phone rebooted, indication of the

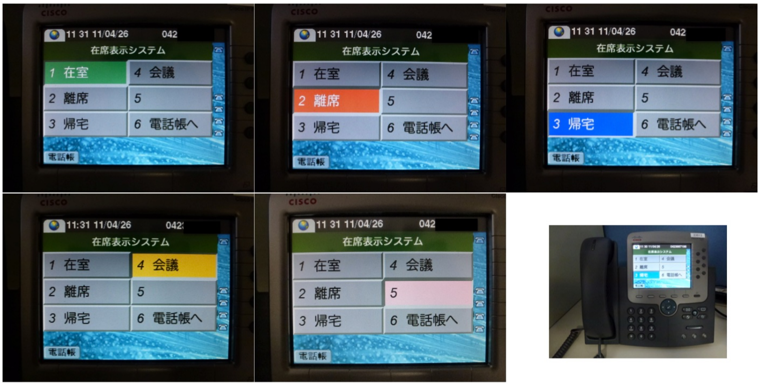

Fig. 5. Touch panel display on IP-Phone

status is different that the user thinks. Therefore we let IP-phone read the last state in the telephone book application server so that a presence indication of the IP-phone did not return to initial state (3. came home) at the time of start and reboot. Therefore, the user should reboot equipment by oneself when the user thought that operation of the IP-phone is strange. By the past use, the wiring of a network is cut temporarily, and there was the thing that operation of the IP-phone becomes strange. Many of these problems were settled by the reset of the IP telephone.

5.3 Construction of a Presence Display Server

In this section, we describe the main function of the a presence display server which we built. We use PHP for the server, because php is easy to use databases.

5.3.1 Connection between the Application Server and the Presence Display Server

The choice state of the menu every IP-phone is stored to a telephone book application server. The presence server publishes an SQL command for this application server and performs reading, renewal. And the presence server checks the update now every ten seconds.

It is often that the user forgets to push the button at the time of return. Therefore we decided to reset status at 4:00 a.m. The reason is because what did not do the time of the reset at 0:00 a.m. works overtime. 4:00 a.m. is the first time for train.

5.3.2 Display of Presence and Phone State

The user watches a list of presence and phone state with a Web browser. These status are updated with Ajax every five seconds. We changed the background

Fig. 6. Display of presence on Web browser

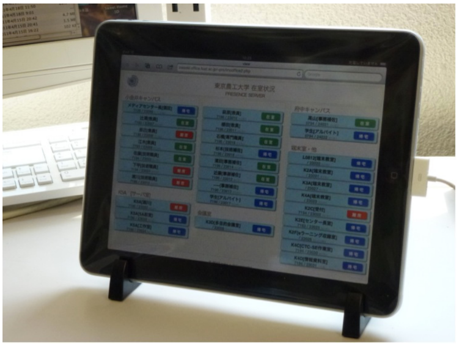

Fig. 7. Display and auto refresh of presence on tablet device

color of the button and a color of listing it into every state so that a user was easy to understand a state. Figure 6 shows the screen of the Web browser of the client-side.

The user used a Web browser on the PC to a client at first. However, there was a problem not to understand a state because Web browser window were not always displayed front of screen on a PC with much agency of the telephone. Therefore, for solution of this problem, we installed tablet devices separately from a PC. In a tablet device, we used ipad and ipad2 for reasons of the resolution (figure 7). We made a URL short cut and was able to call a screen of the presence state immediately.

The telephone state is read by presence display server with API by a telephone book application server. The state of the telephone is displayed with a presence state. The interval of update is the same as presence.

5.3.3 View of log

The a presence and phone status is stored in a MySQL database in the system and outputs this in a specific directory once a day. You can download this log that is CSV formatted via FTP or the access restricted Web page .

In addition, You can display the log graphically every one month (Fig.8). In the graph, the upper shows a presence state, the bottom show a call state. These graphs paint pictures using HTML5 on a Web browser.

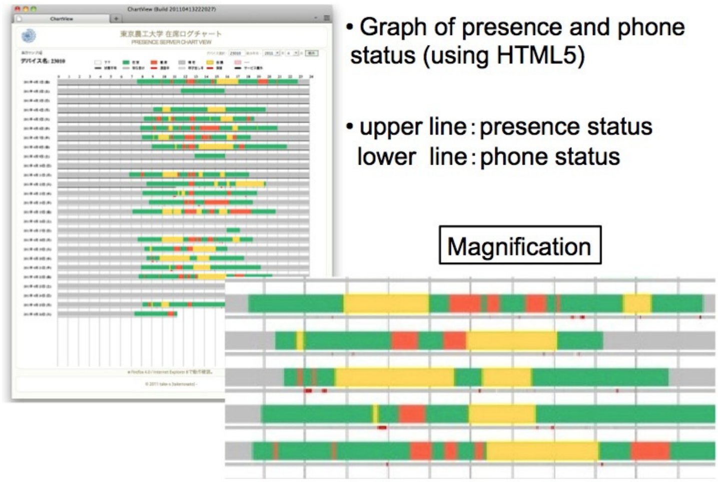

Fig. 8. Graph of system log using HTML5

6 Operating New Presence Display System

This system started use from the middle of October, 2010. We revised a bug and a screen design depending on the demand of the user. The IP telephone introduced about 60 Cisco IP-Phone 7975G. The server except the IP-PBX virtualized it in VMware ESXi and operated it on the same physics server. The virtual server uses outside NAS(Network Attached Storage) to a storage. This NAS stopped with initial defectiveness several times, but the system works without a problem other than it.

It is understand by the log that a user speaks over the phone even if a user chooses "leaving", and a user forgets to change state of "came home" and the status is reset automatically in morning (Fig.8). There was an opinion from a user that it might be possible for conversation when you went to meet by the timing when a call was over.

If a user speaks over the phone, there should be the user in the seat. However, there was the case that a user made a state ”leaving” intentionally. Therefore we did not change state of presence by the state of the telephone automatically.

If a call state watched the timing that was over, I was able to guess whether who and who spoke over the phone. Therefore, it is necessary to be careful when a call state is displayed by a system.

7 Conclusion

This paper is described developing and using of our new presence display system running on IP-phone. We also described the knowledge provided by the construction and use of the before system. Our new system is operating since 2010. Peoples presence status can be viewed through the web browser such as iPad. Presence status on web browser is changed immediately when you change it on an IP-Phone. Because we added the indication of the call state of the telephone to a presence display, you can go to meet a person by the timing when a call was over. This is really performed well.

We operated a new system and have understood it newly. It is to understand it whether who and who called it when it watches a presence display. We plan the expansion to a mobile device and expansion to the use situation of the meeting room now.

Acknowledgments. President Miura of PhoneAppli Inc. shows API of telephone book application to us for this systems construction. We want to thank him.

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3. Microsoft Live Messanger, http://messenger.live.jp/
4. Skype, http://www.skype.com/intl/ja/home/
5. Cisco Systems WebEx, http://www.webex.co.jp/
6. MicroSoft Lync, http://lync.microsoft.com/ja-jp/Pages/default.aspx
7. Nippon Securities Technology Co., Ltd. NSTechno-phone Navi, http://www.nstec.jp/solution/s_menu05_01_3.html
8. PhoneAppli Inc. WEB phonebook, http://phoneappli.net/solution/index.html

Development of a Mobile Tablet PC with Gaze-Tracking Function

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Abstract. In the near future, interfaces for personal information devices with large touch screens that are capable of processing different types of information in a more intuitive manner will become indispensable. In this study, we developed "MobiGaze.PC," a system that can achieve stable gaze tracking on a mobile tablet PC. Users can interactively acquire information using both the touch screen and gaze tracking on a mobile device. First, we created the hardware setup using a tablet PC, cameras, and other apparatus. Next, we developed a method of detecting the eye area using a Purkinje image, and the position of the center of the pupil and the Purkinje image in low resolution. We then performed experiments to evaluate the accuracy of these methods. Finally, we developed a number of multimodal applications of the proposed system.

Keywords: gaze-tracking, mobile device.

1 Introduction

Various personal information devices with large touch screens, such as the Apple iPad, are now widely used. These devices allow for intuitive processing of different types of information. In the near future, such personal information devices will become more multifaceted, and hence, interfaces that can process large amounts of information more intuitively will become indispensable.

Some research has already been conducted in the field of eye tracking using mobile devices. For example, eyeLook was developed by integrating a mobile device and an eye-detection system [1]. Recently, EyePhone was developed, using a mobile phone as the concept model [2]. Further, Holland proposed a system that makes eye tracking possible on an iPad [3]. These approaches, however, do not make it possible to accurately track gaze position. Nevertheless, for precise analysis using a mobile device, one research approach utilized a head-mounted eye-tracker in conjunction with a mobile device [4], while another approach used a desktop eyetracker that was tested by mounting a mobile device on its display [5]. Recently, an option for a portable device was made commercially available by Tobii [6]. These approaches,

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 421–429, 2013.

however, are designed only for the purpose of analysis. NTT docomo in Japan have performed a demonstration of Android tablet with eye tracking function [7].

Much research on gaze interaction, especially for disabled persons, has been conducted for some years now. However, they have not found an alternative approach yet. On the other hand, the authors have focused on the importance of the integration of gaze and touch in practical interaction [8]. A few studies have developed the concept of gaze and touch interaction. For example, Kumar's system uses the gaze and keyboard input for desktop PCs [9], and Stellmach uses an iPod as an input device [10]. The authors have focused on the importance of the integration of gaze and touch in interactions, and have developed an "Eye-Tracking Pen Display," which can achieve precise eye tracking within about 1.0 ° by using an instinctive pen display on a desktop [11][12]. In addition, they have developed "MobiGaze," an interface that allows a user to interact with a personal information device through both touch and gaze [13]. To do so, however, the user must track his/her left eye precisely in order to track his/her gaze on MobiGaze, and must also carry a notebook PC for image processing, and batteries for the auxiliary devices.

In this study, we developed a tablet PC "MobiGaze.PC," an all-in-one system for interactive information acquisition using the instability of camera by using both a touch screen and high precision eye-tracking. First, we developed novel methods of realizing high-speed and precise detection of the pupil and the Purkinje image. Further, we evaluated this system, which is capable of stable eye-tracking on a tablet PC. In addition, we developed some applications.

2 MobiGaze.PC

2.1 Hardware Configuration

We fabricated a prototype of the MobiGaze.PC system, which comprises a tablet PC (HP, EliteBook 2740p, 12.1 inch) and the developed gaze estimation system with stereo cameras (PointGray, Firefly-MV03), as shown in Fig. 1.

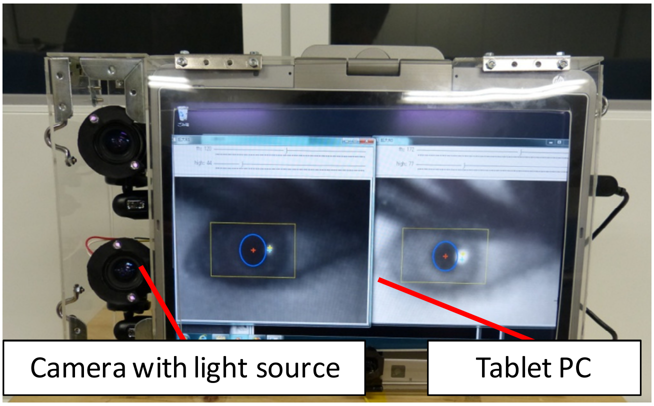

Fig. 1. MobiGaze.PC layout

The cameras must avoid the noise generated by the eyelids and eyelashes. They must also prevent any failure that could be caused by the movement of the arms and hands during touch interaction. For these reasons, we placed the cameras at the left side of the screen. The cameras could capture images with a size of 720 × 480 pixels using an 8 mm lens. With this arrangement, the gaze measurement range could cover the entire area of the screen being used. This setting is suitable for only a right-handed person, and it needs to be mirror-reversed for a left-handed person. The system uses OpenCV1.0 and Intel Integrated Performance Primitives for image processing.

2.2 High-Speed Detection of Purkinje Image

When tracking the gaze using a mobile device, the position of the eye relative to the cameras changes. To track the eye position, we generally detect the face of the user, determine the surrounding area of the eyes, and calculate the position of the pupil [14]. Recently, a number of methods for face detection using a graphics processing unit (GPU) have been introduced, but mobile devices require a high-speed method with high precision [15]. In this study, we developed a novel method that extracts the eye area from a face image using a high-brightness Purkinje image.

There are two phases in this method. First, the method binarizes the face image and detects its edges to estimate an area for extraction of a Purkinje image. The threshold value is determined using Otsu's method, which decreases the variance among classes and increases the variance within a class. Then, after noise elimination, the binarized image is fitted to ellipses. An ellipse resembling the shape of a human face is selected, and its parameters are obtained for area estimation.

Next, the method binarizes the face image to extract a Purkinje image. The threshold value is determined from the parameters of the nearest pixels. The binarized image is fitted to ellipses, and an ellipse resembling the shape of the Purkinje image is selected from an area. This process is shown in Fig. 2.

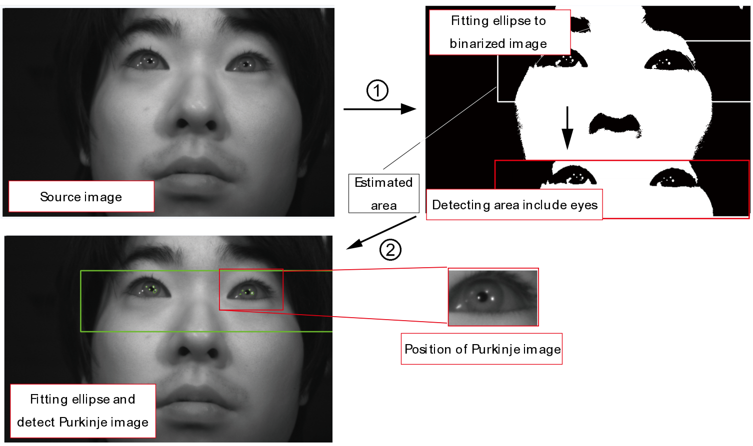

Fig. 2. Detecting position of Purkinje image

2.3 Precise Detection of Pupil and Purkinje Image in Low Resolution

When using low-resolution images, a slight error in estimating the pupil and the Purkinje image has a considerable influence on the accuracy of the gaze. Hence, it is important to detect such errors. One such method is Droege's method of image processing [16]; in this case, however, the processing speed is important. By simplifying image processing, we were able to develop a faster, more stable algorithm.

In this case, the contour was significantly affected by the high brightness of the Purkinje images, which produces strains, as seen in Fig. 3. In order to circumvent this effect arising from the Purkinje image, first, we binarized the low-resolution image and estimated the pupil contour. Next, we performed a convex closure of the contour, which is composed of points. We then determined the center of the pupil by fitting an ellipse to the points that comprise the convex closure contour. As shown in Fig. 4, we can determine the precise ellipse from the contour.

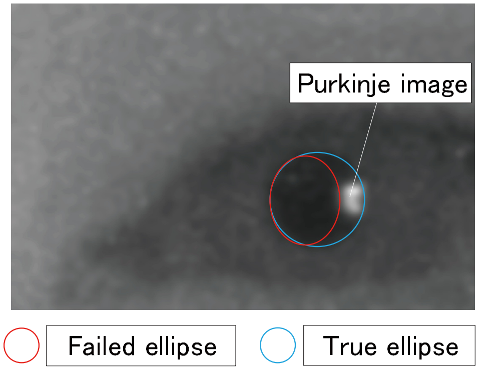

Fig. 3. Unsuccessful pupil extraction

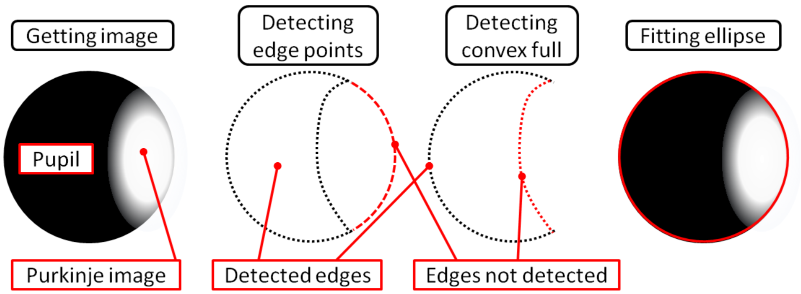

Fig. 4. Process of detecting pupil center

Next, we detected the coordinates of the Purkinje images through binarization. In this case, the Purkinje images resemble a long vertical ellipse. We split the ellipse into two parts, and assumed that the centers of these coordinates are those of the Purkinje image (Fig. 5). After this, we computed the visual axis following one-point calibration to the optical axis [17].

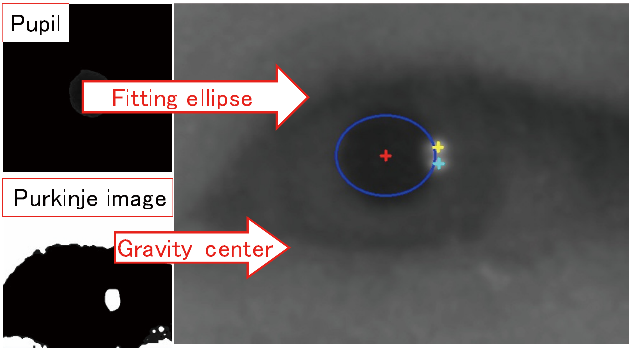

Fig. 5. Image processing for low resolution

3 Evaluation

3.1 Methodology

We then evaluated the MobiGaze.PC system. Fig. 6 shows the experimental setup. The minimum distance between the subject and the display was 30 cm, and the subject was seated in front of the display. In the experiment, to perform the calibration, we requested the user to gaze at the marker on the left side of the display. Next, we showed 12 white crosses on the display in order, and asked the user to gaze at the center of the white cross for over 50 frames. Three students participated in the experiment.

Fig.7 shows the experimental setup for a handheld device. Similar to the previous experiment, we showed 9 white crosses, requested the user to gaze as straight ahead as possible, following which the user moved the MobiGaze.PC system closer to his/her point of gaze. Furthermore, we asked the user to move the device forward and backward by approximately 10 cm. Because the device weighs approximately 2.9 kg, it was supported in order to decrease the burden on the user.

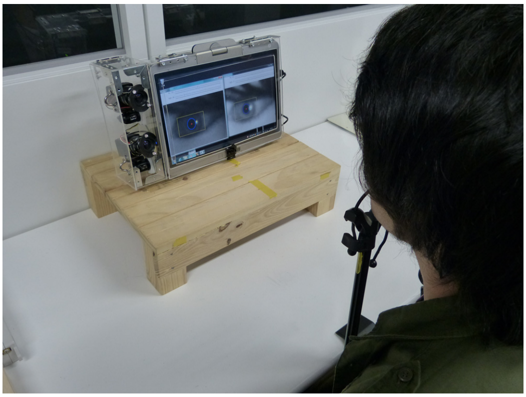

Fig. 6. Experimental setup (handheld)

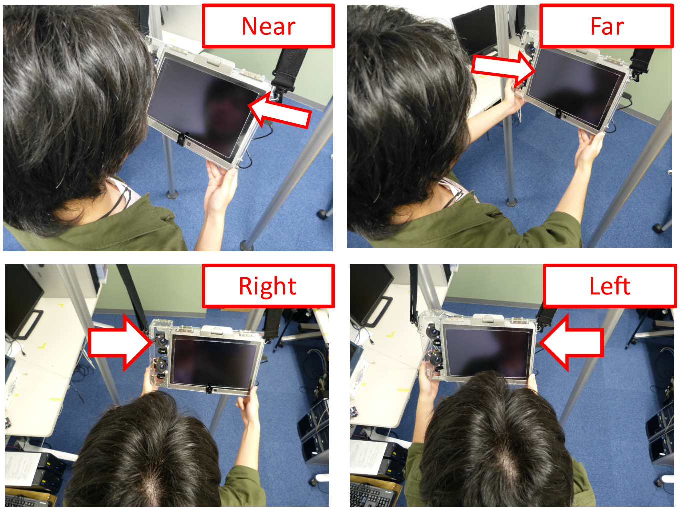

Fig. 7. Experimental setup (handheld)

3.2 Results

Fig.8 shows the results obtained with the device in a fixed position. The average accuracy was about 1.9 °. Fig. 9 shows the results obtained in the experiment with a handheld device. The average accuracy in this case was about 1.6 °. These results confirm that our method can achieve accuracy in the construction of effective mobile-device interfaces. Moreover, our method is flexible, so this system can be used in some circumstances with an editing camera setting. At some points, however, a low degree of accuracy was observed.

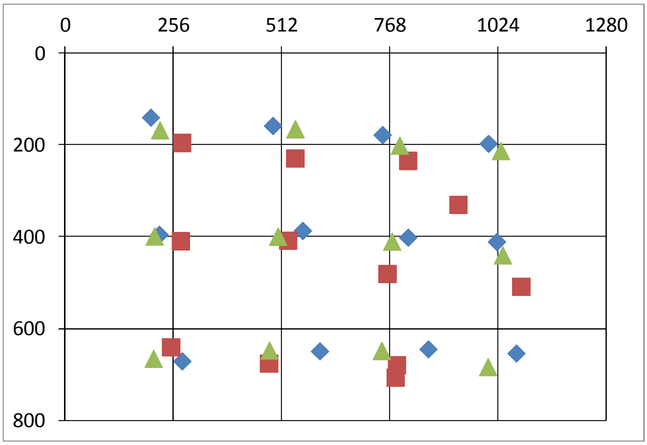

Fig. 8. Experimental results (fixed)

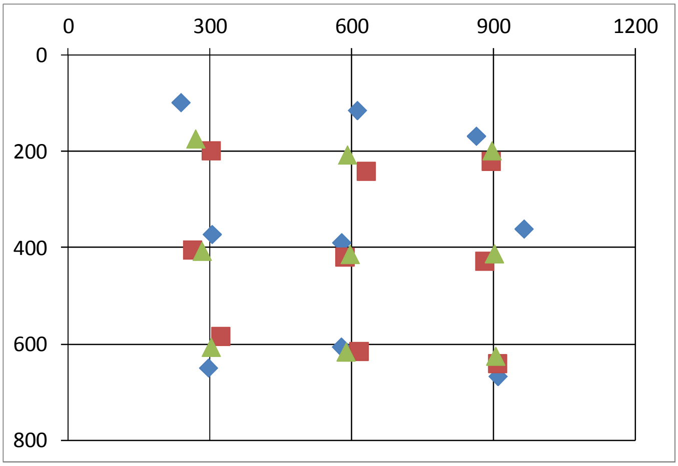

Fig. 9. Experimental results (handheld)

Fig. 10 shows the results of the transition accuracy before and after we changed the distance between the user and the device. The average accuracy was 2.4 °and 1.0 °. These results prove that our method is robust to a certain extent of change in the relative distance between the camera and the eye.

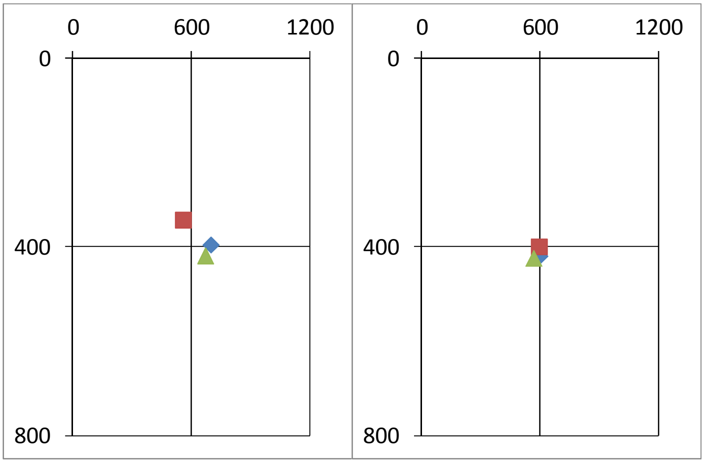

Fig. 10. Experimental results (far and near)

4 Applications

We can propose various multimodal interactions that can be performed using MobiGaze.PC. One is a gaze-and-one hand interaction that can be an alternative to and extension of both hands. For example, when we hold a large-screen mobile device in one hand, the area on which we can physically interact is limited according to the length of our fingers, the position of our hand, etc. Fig. 11 shows extensions of such typical interaction. The other novel form of interaction is direct operation of the gaze point via touch interaction, which can be realized by the all-in-one MobiGaze.PC. This can be applied to various software such as map viewers, picture editors, photo viewers, and three-dimensional maps (Fig. 12). These approaches can not only provide a solution to the Midas Touch Problem but also generate a new operational feeling based upon gaze and touch.

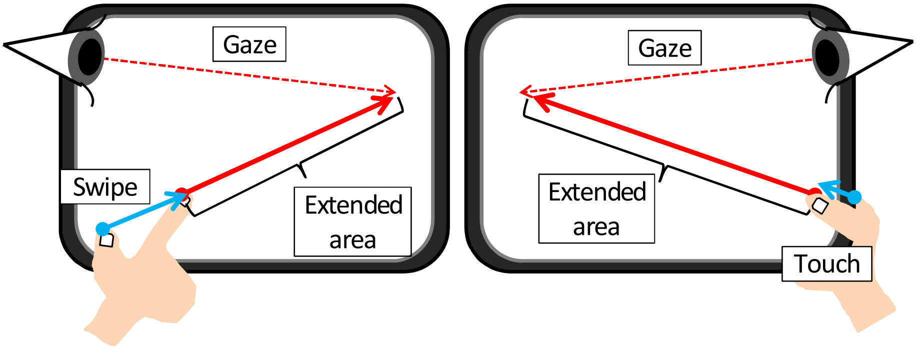

Fig. 11. Extended areas of swipe and touch

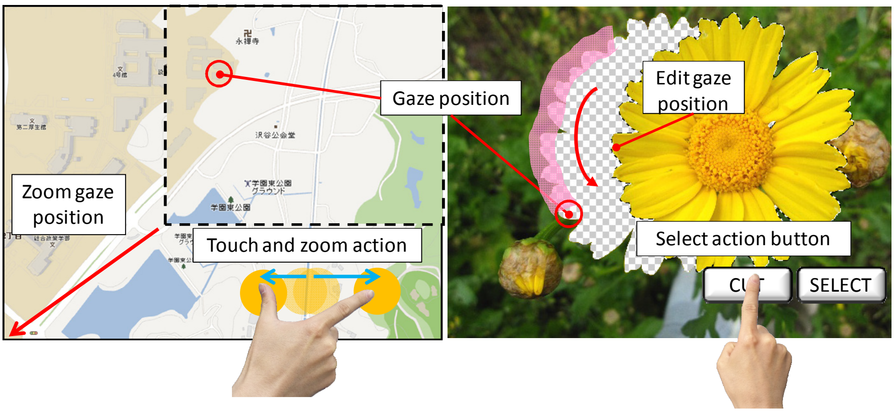

Fig. 12. Applications

5 Conclusion

In this paper, we have described a prototype of MobiGaze.PC, a mobile device that uses gaze estimation in combination with touch input. First, we developed the hardware, which comprises a tablet PC, cameras, and other auxiliary apparatus. Next, we defined a method for high-speed detection of the Purkinje image. We then developed an algorithm to detect the position of the center of the pupil and the

Purkinje image in low resolution. Finally, we performed experiments to evaluate the accuracy of these methods. Two sets of experiments were conducted: one with the device held fixed on a desk, and the other with the device held by hand. The results displayed an average accuracy of 1.9 °and 1.6 °, respectively. Finally, we proposed a number of useful gaze and touch applications for the novel proposed system.

Acknowledgements. A part of this work was supported by KAKENHI (23300047).

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Web- and Mobile-Based Environment for Designing and Presenting Spatial Audiovisual Content

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Abstract. Many types of VR systems have been developed to provide spatial views and surround sound to express high levels of presence. Recently, high-definition TV and 5.1 ch surround sound systems have been made available for watching 3D movies at home. In the near future, more realistic display systems such as "Super Hi-Vision" will be developed and introduced into our homes. However, these types of visual or auditory display systems may require the allocation of a large space for fixed, specialized equipment, and they tend to be expensive. Moreover, compared to the amount of free contents on the Web, highly realistic contents for such systems are still lacking. In this study, we propose a spatial audiovisual display system that comprises multiple mobile devices and a Web-based design system, which allows average users to create and share spatial audio content on the Web.

Keywords: visual and auditory display, mobile device, sound space, sharing, Web.

1 Introduction

Many types of VR systems have been developed that provide spatial views and surround sound for expressing high levels of presence [1–3]. Some of these systems are now available as consumer products, e.g., we can watch 3D movies using high-definition TVs and 5.1 ch surround sound systems at home. The popularity of these systems means that their content is generally available widely. In the near future, more realistic display systems such as "Super Hi-Vision [4]" will be developed and some will be introduced into our homes.

However, these types of visual or auditory display systems sometimes require the allocation of large spaces for fixed, specialized equipment, and they tend to be expensive. Moreover, compared to the amount of free contents on the Web, highly realistic contents for such systems are still lacking. However, mobile devices such as smartphones and tablet PCs are now widespread and service providers such as

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S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 430–439, 2013.

YouTube allow the uploading and sharing of content on the Web. Thus, it may be possible to build an immersive reality system on mobile devices, which users can experience at any time and in any place. It may also be possible to create and share highly realistic content via a Web browser so the interactions between users will facilitate creativity and the volume of available content will increase exponentially.

In this context, we have developed a prototype spatial audiovisual display system using multiple mobile devices [5]. We have also developed a Web-based design system that allows average users to create and share spatial audio content [6]. In this study, we improved their usability, portability, and capacity for expression based on these systems. A combination of these two systems may facilitate the provision of an integrated environment to general users who can enjoy more realistic content.

2 Spatial Audiovisual Display

2.1 Background

In our previous system, we used mobile devices to adjust the scale and composition of the display system to suit the playback environments for users. In this study, we improved this system in four ways. First, we introduced a tablet PC as a visual display to allow greater portability. Second, we implemented a reverberant effect in the auditory display to allow for more effective expression. Third, we implemented a synchronization process between devices to ensure stable operation. Finally, we improved the consistency between virtual and real space.

2.2 System Overview

Figure 1 shows an overview of our proposed system. This system comprises multiple mobile devices for each speaker, a laptop PC with an Head Mount Display (HMD),

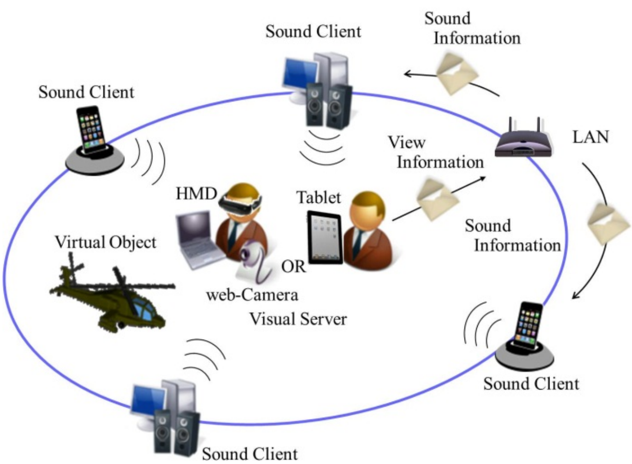


Fig. 1. Overview of the 3D audiovisual display system

and a camera or a tablet for visual information. Each device is connected to a wireless LAN and they are divided into one server and multiple sound clients. In this system, the visual server simulates the virtual space that contains spatial visual and audio data, which can be designed freely by a user. After the simulation, the visual server presents a spatial view to the HMD or tablet display. At the same time, the server transmits the information related to the virtual space to the sound clients via UDP multicast. After the clients receive the information, they implement the spatial sound via each speaker.

In our previous system, an HMD was used to present spatial views. However, with the development of mobile technology, we can now use a tablet to present spatial views as well (Figure 2). To present spatial views to multiple users, a visual client was developed as well as a sound client.

In this system, the visual server and client detect user postures via the gyroscope in the tablet, which is reflected by the viewing angle in the virtual space when presenting the spatial view. The visual server and client also present a mixed view, which comprises the virtual and real space for a user using the camera to generate the visual display. This visual display system is implemented on the same platform as the sound client (Apple iOS); therefore, it is possible to integrate all of the audiovisual display functions into one application. This integration greatly improves the portability and usability of the system, which facilitates the distribution of applications.

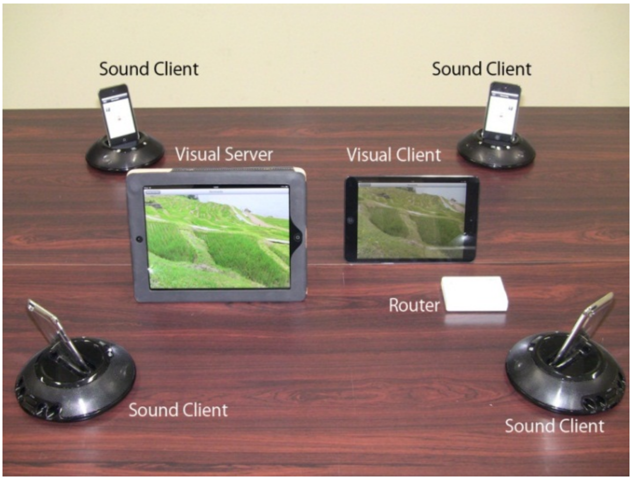
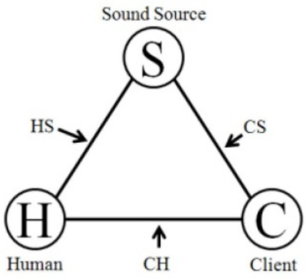


Fig. 2. Image showing the 3D audiovisual display

2.3 Calculation of Playback Sound

Our system reproduces the spatial sound using the sound clients to calculate the distance decrement of sound in three positions (the position of the listener, the sound source, and the sound client, as shown in Figure 3) [7]. Using these three positions,



Sound clients calculate the standard volume value "B" by the following formula.

$$B = | -2HS + CH - CS |$$

The reproduction volume is calculated in the following formula.

$$(1 < B)$$
$$Volume[dB] = Max\ volume[dB] - 20\log(B) - 10$$
$$(0 \le B \le 1)$$
$$Volume[dB] = Max\ volume[dB] - B * 10$$

Fig. 3. Calculation of the sound volume

the system calculates the volume in real time and reproduces a spatial sound based on the volume difference between each client.

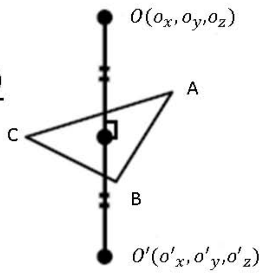
In our present system, if a user inputs the room information data into the system, the sound clients calculate the reverberation and overlays this information onto the

The position of mirror sound is calculated in the following formula.

$$\overrightarrow{CA} \times \overrightarrow{CB} = (n_x, n_y, n_z)$$

$$M = \frac{n_x(c_x - o_x) + n_y(c_y - o_y) + n_z(c_z - o_z)}{{n_x}^2 + {n_y}^2 + {n_z}^2}$$

$$o'_x = 2n_x M + o_x$$
$$o'_y = 2n_y M + o_y \qquad \text{... (1)}$$
$$o'_z = 2n_z M + o_z$$



By using the following formula, reverberation time is determined.

$$T = 0.049\frac{V}{S\alpha} \qquad \text{... (2)}$$

When the time is t, sound pressure level is represented in the following formula.

$$Volume = -4.024\frac{S\alpha}{V}t + Max \qquad \text{... (3)}$$

T : Reverberation time
V : Volume
Sα : Absorption
Max : Initial sound pressure

Fig. 4. Calculation of reverberation

reproduced sound. Figure 4 shows the calculation method. To generate early reflections, this system calculates the mirror image of a sound source (formula (1)). To generate late reverberations, this system calculates the linear equation for attenuation from the early reflections and the approximate reverberation time (formulae (2) and (3)).

In this system, the server only sends position data to the sound clients and it is not concerned with phase variation. On the client side, they prepare playback buffers for early reflections, which are calculated from the room data, and they also prepare 10 playback buffers for late reverberations. After the sound clients receive the data related to the sound source, they calculate the sound volume and delay using the formulae in Figure 3. After the calculation, the clients play the sound sources with the appropriate delay timing and volume, so the correct reverberation is reproduced.

2.4 Synchronization between Sound Clients

In our previous system, the playback timing between clients could lead to the loss of synchronization. This was because the system controlled multiple mobile devices via UDP multicast so the packet was sometimes lost among other network traffic. Therefore, we implemented a synchronization process by calculating the network delay using the Network Time Protocol (NTP) method.

In this method, the server transmits test data to clients and records the sending time. Next, the clients receive the data and record the receiving time, before the clients send a response to the server and record the sending time. Finally, the server receives the response from the clients and records the receiving time. After this transmission, the server checks all of the times recorded and calculates the delays for all clients. The server then sends each delay time to the clients. Following this procedure, synchronization between clients is achieved if clients reproduce the sound source based on the ordinary signal from the server while they control the playback timing based on the delay time.

2.5 Coordination between Virtual and Real Space

In the previous system, a mixed view of virtual and real space was presented via an HMD where a magnetic sensor on the HMD was used to calculate the position and posture of the camera. As a result, the two coordinates were often misaligned and viewing was uncomfortable. In the present system, Parallel Tracking and Mapping (PTAM [10]), which is a marker-free augmented reality technique, is used to coordinate virtual and real space.

PTAM is a method for estimating the real camera position and posture. This method uses one camera and no markers to calculate the 3D map using feature points in real space. Figure 5 shows the coordination process between virtual and real space using PTAM. In this process, the Web camera captures two key frames and initializes the 3D map by calculating the visual features in real space. Next, the visual tracking and updating of the 3D map is executed as parallel thread processes. Visual tracking is achieved by calculating the feature points of the captured images and comparing the

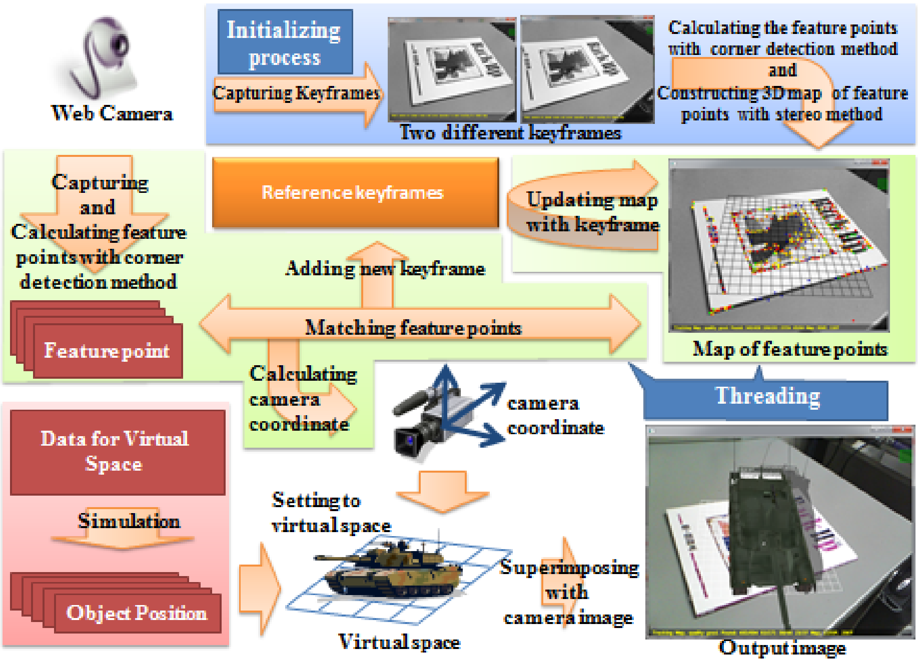


Fig. 5. Calculation of the coordination between virtual and real worlds

points to stored points in the 3D map in real time. At the same time, the system calculates the camera coordinates in real space.

The 3D map is updated by recalculating the map using newly stored key frames at a regular interval. In addition to these threading processes, our system calculates the positions of virtual objects and animates them in the virtual space using another threading process.

Finally, the position of the real camera is transferred to the coordinates of the virtual space and the real view captured by the Web camera is overlaid onto the virtual space. As a result, the final view is presented to the user. In this way, the visual difference between the virtual and real space can be reduced, so a user feels as though a virtual object is placed in the real space.

Our system is implemented at the software level. Therefore, our system can be built at low cost using popular mobile devices. The improvements introduced in this study imply that our system has greater portability, effective expression, and stability.

3 Web-Based Design System for Spatial Audio Content

3.1 Background

Despite the availability of free content on the Web, highly realistic content is not widespread. This is possibly because it is difficult for average users to create content for these systems because this requires specialized knowledge and tools. To address this problem, it is necessary to remove these obstacles [8–9]. In our previous study, we proposed a Web-based design system to allow users to create and share spatial audio content [6]. However, the limitations of the client side technologies (JavaScript, WebGL, and so on) meant that the usability of this system was relatively low. However, recent progress in these technologies has increased the options during implementation. In this study, we improved the usability of our previous system using these technologies.

3.2 System Overview

Figure 6 shows an overview of our proposed system. This system comprises a “design system,” “download system,” and auditory displays. The “design system” is implemented as a rich internet application and users do not need any software other than the browser. With the “download system,” users can search, preview, and download a designed sound space. To enjoy our sound space fully, users can apply our spatial audiovisual display system as explained in Section 2. However, if users do not apply this display, they can still enjoy the sound space via conventional 2 ch speakers on the preview page of a browser. This system can also export the designed spatial sound to a 5.1 ch surround sound format.

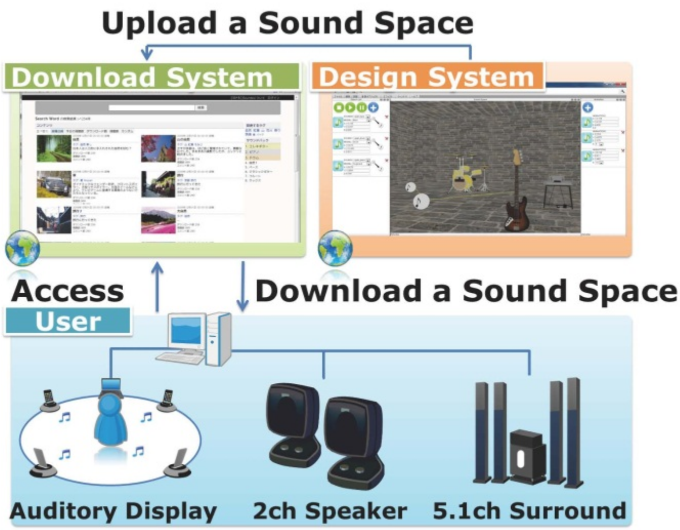


Fig. 6. Overview of the Web-based system

3.3 Designing the Interface

In current tools for designing the sound space, users generally have to coordinate the sound volume of fixed speakers. In our design system, however, users do not have to worry about the playback environment. Instead, they design the sound space by positioning the sound sources and animating them on the browser. Figure 7 shows the window used for designing the sound space. Figure 7-1 shows the “object list window” used to add a sound object and for changing basic object properties (position, audio, and model data). The buttons at the top of window are used to “play,” “stop,” and “pause,” as well as add a sound object. The properties of the

Fig. 7. System for designing the spatial sound content

sound object are located on right-hand side of the musical note icon. With the pull-down menu, users can select the audio data (recorded by users with an ordinary microphone or preregistered data) and the 3DCG model data. A button for the animation mode and a delete button are located on the right-hand side of the properties.

Figure 7-2 shows the “sound space window,” which represents the 3DCG space from the user’s viewpoint. Sound objects are represented as 3DCG models (“COLLADA” format data are imported as external data) where the movement paths are represented as lines and base points (white balls). To move a sound object, users manipulate the mouse cursor on the object by dragging (up, down, left, and right) or rotating the mouse wheel (forward and backward). Figure 7-3 shows the “animation window” known as the “object list window.” In this window, users can specify the animation of sound objects using the button to add movement paths and a text field to add the movement speed.

Using these windows, users can design the sound space content via simple operations. After the design process, the contents are exported as XML data, and users can preview and download the file.

In the “download system,” users can search, preview, and download the designed spatial audio content. At the top of the download system page, users can search for content using certain fields (such as “creator’s name,” “creator’s comment,” and “users’ comments for evaluation”). Figure 8 shows the results of a search. On this page, users click to preview the content, and the preview page and the design page are the same. On this page, users can listen to the designed sound via combined 2 ch speakers. If the users want to arrange the sound space and the permission of the contents is off, they can change the properties of the sound space on this page instantly.

Fig. 8. Download system

Thus, our Web-based design system does not require specialized tools, which allows users to design a sound space intuitively. A combination of the spatial audiovisual display and this Web system is expected to allow general users to enjoy highly realistic content in a more relaxed manner.

4 Conclusion and Future Work

In this study, we improved our spatial audiovisual display system and developed a Web-based system for designing and sharing sound space content.

In current spatial audiovisual display systems, it is impossible to manipulate virtual (or real) objects in real (or virtual) space. However, it is important to consider this virtual–real interaction to achieve hyper-reality. Therefore, in future work, we will introduce a depth sensor such as Microsoft Kinect to produce an interface that facilitates interaction between virtual and real spaces.

In the Web-based design system, we plan to develop a community system to enhance communication and active interaction among users. We will also develop a system to coordinate the sound space with omnidirectional video or 3DCG to produce more attractive content in future studies.

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Part IV

Safety in Transport, Aviation and Industry

Supporting Residents Evacuation and Safety Inquiry in Case of Disaster

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Abstract. Residents' Disaster Prevention Organization (or Self-protection Organization against Disaster) is defined as "voluntary disaster prevention organization based on mutual help of residents" in Basic Counter Disaster Act which was enacted in 1961 in Japan. Although the organizations have national average household coverage ratio of over 75 percent, residents often do not recognize they are registered as member of organization. Furthermore, activities such as safety inquiry, and registration and management at evacuation centers are paper based, making them unable to utilize the latest ICT technologies and resulting in ineffective and inefficient evacuation support activities. In this paper, based on a national web survey conducted in 2011, we will reveal residents' participation in Residents' Disaster Prevention Organization, as well as explore how ICT can support the organizations in times of disaster. In order to change personal data into social information, which is necessary when safety inquiry and registration at evacuation center are conducted under disaster, we propose a prototype information system utilizing QR code and GIS (Geographic Information System), which its effectiveness was validated by questionnaire responded by disaster drill participants.

Keywords: Residents' Disaster Prevention Organization, Evacuation Support, Safety Inquiry Support, QR Code, Geographic Information Systems.

1 Introduction

In Japan where simultaneously decreasing and ageing population[1] has become a social issue, increasing number of citizens such as elderly and handicapped are identified as "people requiring assistance during disasters". Protecting these vulnerable citizens from natural disasters is becoming increasingly important. The Japanese government aims to not only minimize loss of lives but also care for those vulnerable

[1] In the most recent census conducted on October 1st 2010, Japan's population is 128,057,352 and 23.1% of the population is 65 years or older. Based on a report released by the National Institute of Population and Social Security Research in January 2012, Japan's population has been decreasing since 2009 and will continue to decrease by about one million every year.

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 443–452, 2013.

citizens during and after evacuation by capturing the whereabouts of vulnerable residents beforehand and issuing evacuation preparation orders aimed specifically for them. The idea is represented as “Guidelines for Evacuation Support of People Requiring Assistance during a Disaster” set by the Japanese Cabinet Office in 2005 or in regional disaster prevention plans drawn based on “Basic Disaster Countermeasure Act” enacted in 1961. “Residents’ Disaster Prevention Organization (or Self-protection Organization against Disaster)” based on residents’ mutual help is stipulated in the Basic Disaster Countermeasure Act as one of apparatuses to achieve the goal, i.e. to save and support each other in spirit of mutual help in times of disaster.

This residents’ disaster prevention organization covered only 43.8% (coverage ratio is calculated as number of households belonging to an organization divided by total number of households present in the relevant region such as municipality or prefecture[2] of households with 70,639 organizations in 1995 at the time Great Hanshin Earthquake which caused more than 6,000 deaths. The ratio has seen significant increase since then due to increased consciousness against disasters especially mutual help among residents, and encouragement from local municipalities as part of anti-disaster policies. According to Fire and Disaster Management Agency of Ministry of Internal Affairs and Communications, 146,396 residents’ disaster prevention organizations are active in 1,625 municipalities out of 1,747 nationwide, covering 75.8% of households as of April 1st 2012.

However, when we ask people whether they are members of residents’ disaster prevention organization on various occasions, only 10% to 20% answer they are, suggesting that there might be a gap between coverage ratio and actual percentage of people who are actively aware of their membership. In a July 2005 survey by the cabinet named “Survey on Flood and Landslide Disasters” only 19.1% residents answered that they are actively participating in activities of residents’ disaster prevention organization, compared to 64.5% coverage ratio at the time. This indicates that although organization of residents’ disaster prevention organization has seen progress, it may have not involved mobilization of member residents to participate in activities such as drills.

To answer these research questions we conducted a nationwide web survey with 7,133 valid responses on the topic of residents’ disaster prevention organizations in 2011, just before the occurrence of Great East Japan Earthquake. As a result it was shown that only 9.2% of respondents were aware that they were members of residents’ disaster prevention association, confirming our doubts that there might be gaps between coverage ratio and actual number of people involved in the organizations’ activities. Also, our survey indicated that there are number of respondents who knew they were members of the organization but did not know in detail about their assigned roles in residents’ disaster prevention organization.

Though it is important to organize residents’ disaster prevention organizations, it alone will not make the organization functional under disasters. We believe that publicity of organization’s significance, goals and activities is necessary for increasing participants in drills which are necessary for residents’ disaster prevention

[2] There are 47 prefectures and 1,747 municipalities as of January 1st 2013 in Japan.

organization to achieve its goals under normal times and disasters. However, there are no websites operated by organization for publicity. Speaking of information technology, there are also no information systems that can support the activities of residents' disaster prevention organizations.

In this paper, we will discuss the issues and possibilities of supporting residents' disaster prevention organizations through ICT based on our web survey of 2011 and a series of empirical studies on evacuation and safety inquiry support including the latest study conducted on February 26th 2012 in Minagidai school district of Miki City, Hyogo Prefecture. We will also show the effectiveness of using QR code to collect personal data needed in process of safety inquiry and registration at evacuation center correctly, promptly and simply.

2 Current State of Residents' Disaster Prevention Organizations

As mentioned above, we conducted a survey titled "Web Survey on Residents' Disaster Prevention Organizations" from January 19th 2011 to February 24th 2011.

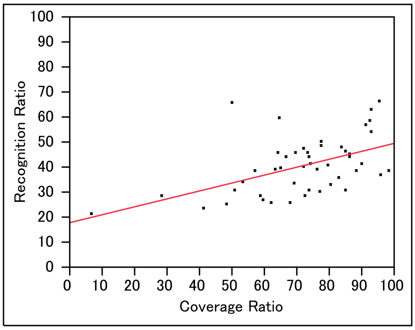
The survey was a voluntary web survey consigned to Data Service Incorporation. Asked items included: 1. Personal attributes; 2. Experience of struck by disaster and evacuation, and knowledge of nearest evacuation center; 3. Membership of residents' associations[3]; 4. Knowledge on disaster prevention associations, participation in its activities and evaluation of its activities; 5. Whether respondent wish to join residents' disaster prevention organizations' activities and what kind of activities are preferred (in case respondent did not participate in activities); 6. Necessary policies that will result in more active residents' disaster prevention organizations; 7. Measures taken personally against disasters; 8. Whether respondent is willing to help elderly or handicapped neighbors; and 9. Evaluation of self, mutual and public help by ordering them by importance and allotting points out of 100 to each of them. 7,133 valid responses were obtained.

Although we have to take into account possible bias caused by sampling selection through voluntary web survey, it was revealed that national recognition ratio of residents' disaster prevention organization was 37.6%. Fig. 1 shows scatter diagrams of prefectural recognition ratio, interest ratio, participation ratio and willingness to participate ratio against coverage rate. From Fig. 1 we can observe large gaps between activity coverage rate and recognition ratio, consciousness of participation ratio and willingness to participation ratio.

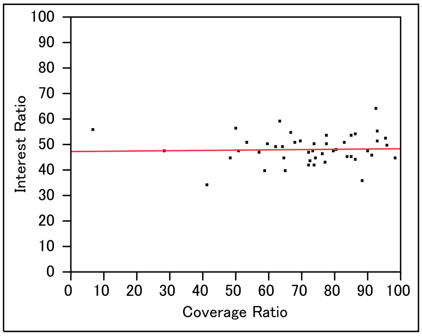
Furthermore, although 9.2% responded they are aware of their membership in residents' disaster prevention organizations, there were 59.6% who were not aware of their role in the organization, 48.6% who did not actively participate in activities,

[3] Residents' association is another voluntary based neighborhood level organization which manages local common assets such as garbage collection sites, parks and neighborhood meeting places. Residents' associations have a long history and are different from residents' disaster prevention organizations, but residents' disaster prevention organizations are usually established based on residents' associations.

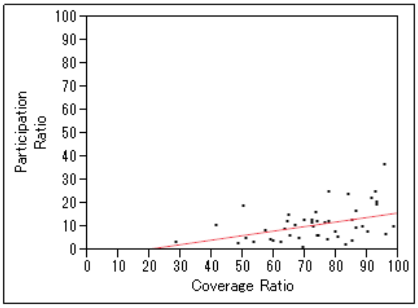
38.9% who felt that the organization was not active enough, and 25.7% who did not evaluate the organization's activities. These results show that even amongst conscious members, participation and evaluation varies from respondent to respondent, which makes effectiveness of residents' disaster prevention organizations questionable.



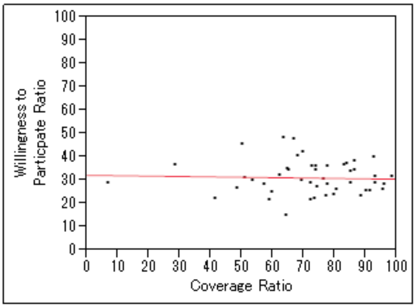
N = 47, r = 0.503, R^2 = 0.253
y = 17.781 + 0.314 x, F-value = 15.261



N = 47, r = 0.045, R^2 = 0.002
y = 47.062 + 0.014 x, F-value = 0.089



N = 47, r = 0.476, R^2 = 0.226
y = -3.357 + 0.197 x, F-value = 13.137



N = 47, r = -0.038, R^2 = 0.001
y = 32.315 - 0.015 x, F-value = 0.065

Fig. 1. Relationships between Prefectural Activity Coverage and Recognition, Interest, Consciousness of Participation and Willingness to Participate of Self-protection Organization against Disaster

Lack of publicity of residents' disaster prevention organization's presence and activities is one possible cause that results in these gaps between nominal coverage ratio and actual recognition and awareness of membership. Although there are a number of local municipalities that introduce residents' disaster prevention organizations on their media, giving updates on events and activities, from our survey their effect seems to be limited. Also, because each local municipality provides their information in their own different manners, it is unclear where to look in order to obtain needed information. This might be an obstacle for residents to find information on residents' disaster prevention organization which they are unaware of in the first place.

In order to activate and functionalize the activities of residents' disaster prevention organization, support in terms of information systems is also necessary. Activities of residents' disaster prevention organization under normal times cover: 1. Publicity of disaster prevention measures; 2. Mapping level of danger or hazard in its region; 3. Disaster prevention drills; 4. Checking safety of homes; 5. Maintaining materials and equipment; 6. Planning measures for vulnerable residents; and 7. Cooperation with other organizations. Activities under disaster will include: 1. Collection and communication of information; 2. Preventing fire; 3. Initial stage firefighting; 4. Rescue and first aid; 5. Evacuation support; 6. Operation and management of evacuation centers; and 7. Supplying food and water.

Information systems will be beneficial in aiding these residents' disaster prevention organizations' activities. For example, lectures on firefighting and first aid can be given through websites or applications to enhance effectiveness, and GIS (Geographic Information System) can be used to visualize regional information and hazard levels to aid planning and management of evacuation. During disaster, disaster resistant lines of communication can be used to share needed information between each local evacuation center and an anti-disaster headquarters organized in each municipality in times of disaster. Currently residents must rely on analog bulletin boards and posted papers to know safety of their relatives and friends, but if information could be shared and centralized to the anti-disaster headquarter, information needed safety inquiry could be provided on a single point of contact instead of residents having to travel around multiple evacuation centers.

3 Evacuation Support System Using QR Code

We have been conducting a joint study with Miki City in Hyogo Prefecture from 2006 in order to develop information system for anti-disaster headquarters and residents' disaster prevention organization, involving a number of field studies in cooperation with the city and PASCO Corporation [1, 2, 3, 4]. Fig. 2 shows a sample screen of information system for anti-disaster headquarters which support manager of anti-disaster headquarters to grasp the status of region where evacuation order might be issued.

From fiscal year 2011 to 2012 we conducted an empirical study using a prototype of our evacuation and safety inquiry support system developed with PASCO Corporation, with financial support from Japan Science and Technology Agency. The study was conducted in a disaster drill of Minagidai elementary school district on February 26th 2012.

In Miki City, when a resident enters evacuation center, he or she is required to fill in a household based and A4 sized evacuation center registration form with fields such as names of family, phone number, residing address, and emergency contact

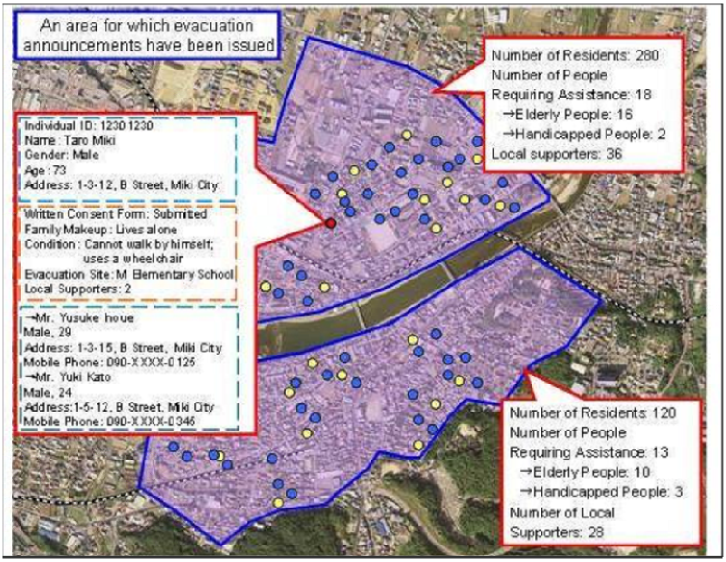


Fig. 2. A Sample Screen of Our Prototype System for Anti-disaster Headquarters

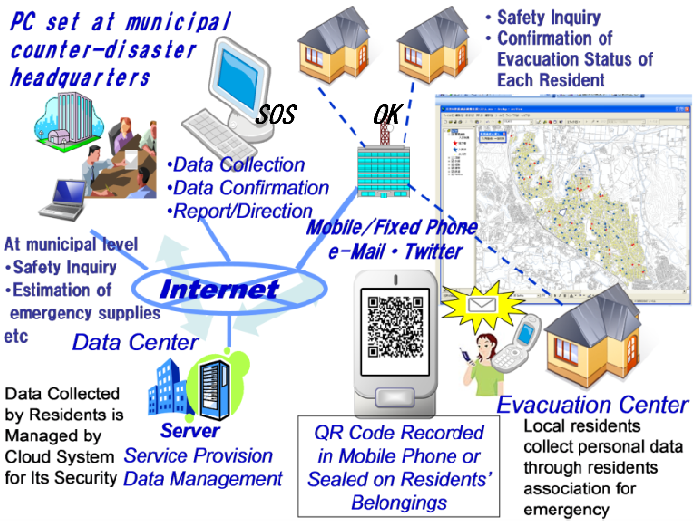


Fig. 3. Overview of the Developing System

address. These forms take considerable time to complete which causes congestion at evacuation center registration. In addition, because evacuation forms are paper based it is difficult to keep track of number and structure of evacuees in a real time manner. Furthermore, in an emergency situation handwritten forms may be difficult or impossible to read, all which could lead to problems in management of evacuation centers and safety inquiry. Our system aims to digitalize this registration process as shown in fig.3. Information required in evacuation registration form is pre-registered in a database so that registration can be done using name or phone number as matching key, improving efficiency in registration. For those who fear exfiltration of personal data and do not wish to be pre-registered, QR code is used to digitalize the necessary information so that registration can be done by scanning the evacuee's QR code as shown in fig.4. The reasons for using QR code are: 1. Others cannot read the contents without scanning the code; 2. It can be carried easily by printing it on a name card sized paper or saving it on mobile devices; and 3. It can be read quickly by a common two-dimensional barcode reader. For those who prefer neither of our solutions, conventional method of paper based registration is provided as well.

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Fig. 4. Example of QR Coded Personal Data

Also, as shown in fig.5, status check of evacuation and management of evacuees is enabled by linking the registered information to a GIS based evacuation support system. Furthermore, for those who are safe at home or require assistance, we plan to prepare two mobile phones—one for reporting safety and one for requesting assistance or rescue—so that residents can make one ring calls to notify the manager of residents' disaster prevention organization or the staff of municipal anti-disaster headquarters. If phone number is pre-registered in the database, it can also be marked in our system to update the visualization.

In order to test effectiveness of our newly developed residents' evacuation support and safety inquiry system, we distributed questionnaire surveys to each participant upon completion of registration procedure and collecting them at end of the drill. Out of 214 survey sheets, 148 were retrieved. The survey sheets asked evaluation of the following in addition to personal attributes such as age and gender: simplification and speedup of registration, increasing accuracy of registration, supporting operation of evacuation centers, effectiveness of safety inquiry using GIS, effectiveness of registration using QR codes, effectiveness of safety inquiry using one-ring calls, whether respondent have fear of information leakage upon pre-registration, whether respondent wishes to register to our system, and whether respondent wishes to use QR code.

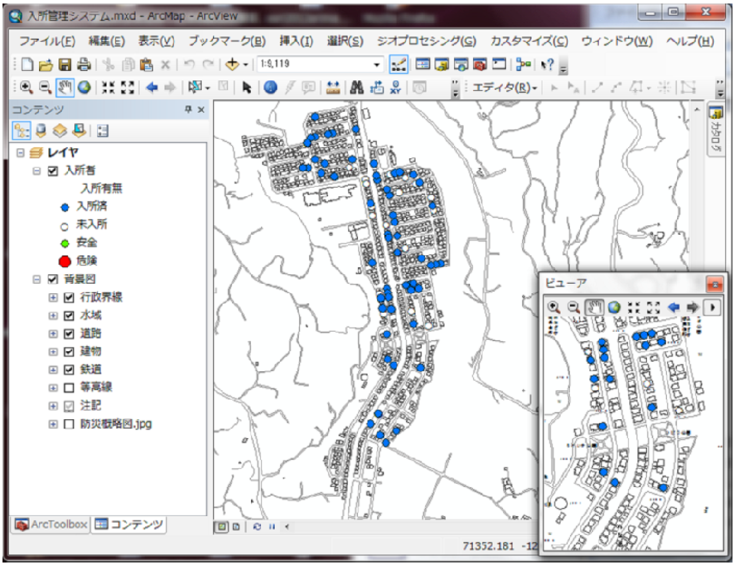

Fig. 5. A Sample Screen of Our Prototype System: White circle, blue circle, green circle and red circle mean pre-registered household, household already evacuated, household staying at home safely and household requiring help or rescue.

Number of respondents who registered through our system and number of respondents who registered by conventional method are roughly equal. Through the survey it was shown that a high proportion of 73.0% have some fear regarding information leakage. As to our system itself the majority—over 80%—of respondents have evaluated it favorably: 89.9% for simplification and speedup, 87.8% for increasing accuracy, 83.1% for supporting management of evacuation centers, and 91.9% for safety inquiry utilizing GIS. Also, responses are also positive for safety status confirmation through telephone calls (74.3%) and embedding personal information in QR codes (79.1%) leading to a positive feedback to our system in general where 89.2% responding they wish to consider about pre-registration and 79.0% responding they wish to consider using QR coded cards. We believe that this confirms effectiveness of the system we have developed in this study.

4 Need for Systems to Support Residents' Disaster Prevention Organizations

One example of information system in action during disaster would be the "Osaka 8.8 Million Drill" conducted in Osaka Prefecture on September 5th 2012. In this disaster drill emergency earthquake information was sent through emergency radio and email networks of mobile phone carriers—NTT DoCoMo, AU and Softbank—on 11:00 AM, urging citizens to simulate how they could ensure safety and reflect upon what should be done after securing safety. In this drill several problems such as certain models of mobile phones not receiving the mail and Osaka prefecture's website becoming overwhelmed by traffic were discovered. It was shown however, that the scheme of informing emergency information through mobile phone carriers' network was an effective solution.

In the evacuation stage that follows this stage however, there has not been an establish scheme to support evacuation such as checking status of each residents' evacuation, safety inquiry and managing evacuees at evacuation centers. Challenges at this stage have been pointed out in the Great East Japan Earthquake, where people had difficulties checking the safety of their relatives and friends.

In order to solve such problems, it is best to manage the information of evacuees and safety status of residents in a digitalized manner so that information can be obtained instantly, with necessary measures to protect personal information. In other words, we need to construct a scheme where appropriate information can be distributed under emergency while ensuring their secrecy is kept under ordinary times.

5 Conclusion

To make activities of residents' disaster prevention organizations more effective, first it is necessary to increase the number of people participating by informing the presence and detailed activities of the organization. In publicity it might be beneficial to apply consumer behavior theories such as AIDA (attention, interest, desire, action), AISAS (attention, interest, search, action, share) and SIPS (sympathize, identify, participate, share and spread). The latter two applies especially to web based marketing, and media such as websites and social networking services could prove useful for this purpose. Efforts in making such media more attractive such as integrated and interactive design of webpages and utilizing multimedia contents will be necessary as well.

Also, considering that the digital era has already arrived, support of residents' disaster prevention organizations should shift from papers to digital, utilizing ICT. It must be noted however, usability and durability under emergency situation is required for such ICT measures to be effective, which poses us challenges such as securing electricity and developing interfaces which everyone can use. Furthermore, systems must be of use under ordinary times as well as emergency times, or users will not be able to fully utilize the system when disaster suddenly strikes. Considering that residents' disaster prevention organizations are organized based on neighborhood associations, name lists and membership fee collection lists will be resources that we can utilize.

Although our system currently uses dedicated barcode readers combined with QR codes printed on paper, dedicated devices are costly and can become single point of failure if they are broken or lost. Printed QR codes also have problem of being vulnerable to wears and tears. To solve these problems we plan to use the ubiquitous mobile devices to read and display QR codes. Tablet PC might be easier to use than ordinal PC and yet more powerful than mobile phones in times of disaster. Because municipal information systems were destroyed in the Great East Japan Earthquake, cloud systems could be utilized to increase resilience of systems under disaster. We will continue to improve our system based on these ideas.

Acknowledgement. This paper is based on the joint research programs with Shingu Town in year 2005, Miki City from year 2006 and PASCO Corporation from 2006. This research is partially supported by the Japan Society for the Promotion of Science under grant No. 20310097 from fiscal year 2008 to 2010 and grant No. 24530417 in fiscal year 2012, and A-STEP (Adaptable and Seamless Technology Transfer Program through Target-driven R&D) grant No. 11-185 in 2009 and A-STEP grant No.AS232Z02153A in 2011 and 2012 from Japan Science and Technology Agency.

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Safety Culture: An Examination of the Relationship between a Safety Management System and Pilot Judgment Using Simulation in Aeronautics

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Abstract. The need to reduce aircraft accidents and incidents is paramount in general aviation, specifically, those attributed to aeronautical decision-making and poor judgment. Accident statistics confirms aeronautical decision-making and poor judgment as a significant contributor to general aviation accidents and incidents (Aircraft Owners and Pilot Association, 2010). The absence of a positive safety culture in general aviation to include training organizations affects pilot judgment and decision making. The learning process and education through actual and simulated flight training and the relationship of a positive safety culture during the learning process and training is of importance and currently under study using the Frasca mentor Advance Aviation Training Device.

Keywords: Aeronautical Decision-Making, Judgment, Advance Aviation Training Device, Safety Management System, Situational Judgment Test Modified.

1 Introduction

Important aspects of decision-making theory and human factors are based on errors in judgment, the learning process, and organizational culture (Dietrich, 2010; Erwin & Anderson, 2011; Robertson, 2004; Schriver et al., 2008). The current study is in progress and completion is expected to be July of 2013. Statistical results and conclusions are expected late 2013. The study and additional research could contribute to the field of aviation safety and aeronautical decision making by detailing the relationship between positive safety cultures emanating from Safety Management System and pilot judgment among pilots with varying levels of flight experience in a pilots naturalistic environment using simulation. Additional contributions anticipated are the effects of a positive safety culture for private pilots during simulated critical flight scenarios and the impact of pilot judgment on recommended scenario solutions in naturalistic environment.

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 453–459, 2013.

2 Role of the Federal Aviation Administration

The role of the Federal Aviation Administration and flight training schools in establishing a positive safety culture during training is crucial. The literature, "Evaluating the Decision Making skills of General Aviation Pilots (Driskill et al., 1998)", "Safety Management System Guidance: National policy (Federal Aviation Administration, 2008c)", and "Air Safety Institute: 2010 Nall Report (Aircraft Owners and pilot Association, 2010)," all support the importance of pilot judgment and improving safety in aviation through various means.

Aeronautical Decision-Making (ADM) skills are acquired from the start of one's pilot training. The importance of ADM skills is recognized by the FAA and aviation industry through various publications (Federal Aviation Administration, 2008c; Kennedy, Taylor, Reade, & Yesavage, 2010; O'Hare, 2002; Stolzer et al., 2008). This recognition prompted the FAA to issue Advisory Circular 120-92a, Safety Management Systems for Service Providers. The circular details the importance of establishing a Safety Management System (SMS) incorporating safety promotion through a positive safety culture, policies, risk management, and hazard identification and management (Federal Aviation Administration, 2010e). This advisory circular falls short in the mandate for implementing an SMS program in general aviation to include flight-training facilities.

3 Simulation for Aeronautical Decision Making

The Frasca mentor, Advance Aviation Training Device (AATD), incorporating Synthetic Automated Flight Training Environment with Virtual Air Traffic (SAFTE-VAT) is being used to create a realistic flight and communications environment, and simulate critical flight scenarios, flight profiles, and procedures in a pilot's natural environment. The Frasca Mentor is compact in size (see Figure 1 and 2) providing high quality flight replication and fidelity comparable in technology to FAA approved level two through seven flight training devices and flight simulators. The AATD replicates the Cessna 172S NAV III aircraft, a single engine, fixed gear, high wing aircraft with state of the art avionics and flight instruments.

The Frasca Mentor enables research to be completed in a realistic simulated flight environment without risk to the pilot or researcher. Five critical flight scenarios have been programmed into the mentor to replicate a real life scenario or crisis during flight requiring communications with Air Traffic Control facilities. Communications using SAFTE-VAT enhances the realism of the naturalistic simulated environment. A researcher is able to observe and record immediate responses from the pilot's during each critical scenario encountered during the VFR flight. SAFTE-VAT engages pilots with virtual ATC communications and provides fidelity to a degree similar between simulated and actual flight environments (Coman, et al, 2011). Designers developed SAFTE-VAT for use during simulation-based flight training with the aim of decreasing instructor pilot workload and increasing the behavioral fidelity when immersed in a virtual training environment (Macchiarella & Doherty, 2007).

Fig. 1. Frasca Mentor Advance Aviation Training Device (AATD). The training device replicates the cockpit of the Cessna 172, G1000 configuration (Frasca, 2010).

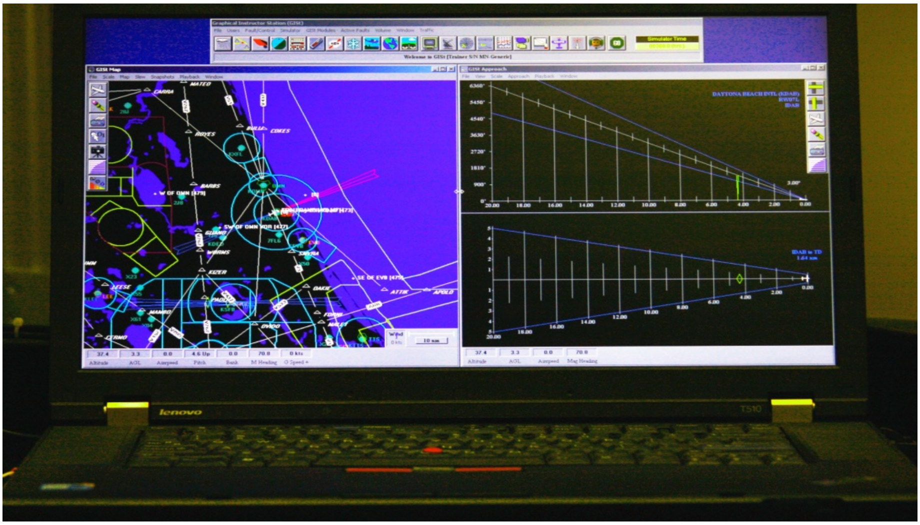

Fig. 2. Frasca Mentor Graphic Instructor Station (GISt). The GISt is Frasca's computer based instructor station using a Graphic User Interface (GUI) to control the AATD (Frasca, 2010).

Proposed research would consist of testing for a main effect, positive safety culture association, and testing for an interaction effect between positive safety culture association and pilot experience based on a Situational Judgment Test Modified (SJTM) scores attained by participants. The Situational Judgment Test Modified will be administered during a simulated Visual Flight Rules (VFR) cross-country flight in the Frasca mentor, Advance Aviation Training Device. The SJTM contains five critical flight scenarios used to attain participant's scores. The five scenarios were chosen based on the likelihood of a private pilot encountering the scenarios during actual flight. The scenarios were adapted from an FAA pencil and paper Situational Judgment Test conducted in 1998 (Driskill, et al., 1998).

4 Method

Proposed research would address the absence of a positive safety culture in general aviation including flight training organizations (Helmreich, Wilhelm, Klinect & Merritt, 2001; Stolzer et al., 2008). This absence necessitates the need for investigating the effects of safety cultures emanating from SMS on pilot judgment to include the ADM process (Allen, 2008; Federal Aviation Administration, 2010c; Joint Safety Analysis Team, 2002; Shappell &Weigmann, 2000; Stolzer et al., 2008) during the simulation of flight.

The proposed study would uses private pilots with varying levels of experience. The two independent variables are positive safety culture with two levels: (a) pilots who attained a private pilot certificate from an aviation flight training school having a positive safety culture emanating from SMS; and (b) pilots who attained a private pilot certificate through individual instruction not affiliated with an aviation flight training school having a positive safety culture emanating from SMS. Independent variable two is pilot experience. Independent variable two has two levels: (a) less expert private pilot; and (b) more expert private pilot and is classified by total hours attained after a private certificate. The dependent variable relates to a pilot's ability to make appropriate and timely decisions during critical flight conditions to include but not limited to: a) mechanical failures, b) severe weather identification and avoidance, and c) take off and landing phases of flights as measured by the SJTM. The decisions require sound judgment, attention to detail, and the execution of appropriate corrective action or procedures.

5 Discussion

The theory of decision-making (Bordley, 2001; Dayan, 2008; O'Hare & Wiggins, 2004; Robertson, 2004) can assist in explaining why pilots make poor decisions and exhibit poor judgment. Increasing knowledge and experience alone does not assist in changing poor decision-making and judgment. A significant amount of research has been conducted in the field of decision-making (Cohen, 2008; Cook, Noyes, & Masakowski, 2007; Hastie, 2001; Klein, 2008). Good decision-making practices reduce or mitigate errors during various phases of flight to an acceptable level.

Gaps in previous research (Bordley, 2001; Jensen, 1995; O'Hare, 2002; Mellers, Schwartz & Cook, 1998; Robertson, 2004) demonstrate a need to expand and conduct pilot judgment and decision collection and evaluation during the naturalistic phase of pilot operations. The phase of operations would include simulated and actual flight, and the relation of experience and decision-making. Previous research used scenario based survey questions such as a Situational Judgment Test to gather data from pilots

(Hunter, 2003) but the research did not address the capacity of individuals to influence good decision-making.

Prior research used various written instruments in studying aeronautical decision making as well as Situational Judgment Test (SJT) and surveys (Driskill et al, 1998; Kochan et al., 1997). The use of a SJT has demonstrated effective reliability in evaluating pilot skills and examining individual reactions in certain circumstances (Driskill et al., 1998). Driskill (1998) devised a written SJT instrument for evaluating decision making by general aviation pilots. The instrument, although demonstrated effective reliability in evaluating pilot skills, did not expose pilots to conditions experienced during actual or simulated flight. This methodology lacks in exposing pilots to conditions typically experienced during simulated or actual flight such as environmental noise, situational awareness, device and functional fidelity, and cockpit resource management.

6 Conclusion

Further research is projected based on the initial and anticipated results upon completion of the research and the aviation industry wide acknowledgement of pilot error as a major cause of general aviation accidents. Many studies have been completed and recommendations made to reduce human error. The benefit of additional research lies in the way we manage human error through a systematic approach such as SMS and educating pilots starting at the beginning of one's aviation endeavors through exposure to simulation and actual flight.

Additional research could contribute to the field of aviation safety and aeronautical decision making by detailing the relationship between positive safety cultures from SMS and pilot judgment among pilots with varying levels of flight experience. Contributions anticipated are the effects of a positive safety culture for private pilots during simulated critical flight scenarios and the impact of pilot judgment on the recommended critical scenario solutions during a naturalistic environment. The data collected may have implications on future procedures, training, and requirements for flight training.

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What, Where, and When? Intelligent Presentation Management for Automotive Human Machine Interfaces and Its Application

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Abstract. In the past years we have seen overwhelming information abundance in the automotive domain. Numerous advanced driver assistant systems (ADAS) and in-vehicle information systems (IVIS) are introduced even in middle-sized class cars. In the future, new technologies based on Vehicle-2-X Communication (V2X) open a wide range of safety, traffic efficiency and infotainment applications. In order to ensure driving safety, user-friendly information presentation and interaction are inalienable for automotive applications. However, conflicts between numerous applications running in parallel will inevitably occur: On the one hand, there exist spatial and technical constraints at a driver's workplace. On the other hand, a driver has limited cognitive resources to spare for additional information perception. This paper elaborates on a generic Automotive HMI concept, which provides a coordination layer for independent applications. The implementation was applied to a field operational test for V2X providing a suitable test-bed for evaluation in real traffic scenarios with over 30 applications.

Keywords: Presentation Management, V2X Communication, Human Machine Interfaces.

1 Introduction

Advances in technology led to an increasing number of in-vehicle applications over the last years. Numerous advanced driver assistant systems (ADAS) help the driver to recognize and avoid critical situations in everyday driving scenarios. Moreover, in-car entertainment is also demanding attention from the drivers. The connected car provides services not only related to driving. Besides Point of Interest or parking information, Internet access is used to transform the drivers' workplace into a mobile office: texting while driving, message notifications, phone calls and so on are only some examples of today's automotive applications.

In the near future, Vehicle-2-X Communication (V2X) will introduce even a wider range of additional applications to the connected car [1]. Within the V2X domain, cars are not only communicating over the Internet but also with other vehicles, road

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 460–469, 2013.

infrastructure and traffic management authorities by using special wireless communication protocols. After market introduction, V2X will contribute not only additional safety related application to existing ADAS but also traffic efficiency and value-added services [2]. Up to today, these in-car applications act independently from each other and present information without being aware of currently active presentations to the user. This inevitably leads to presentation conflicts that degrade usability, which in turn affects driving safety: On the one hand, there exist spatial and technical constraints at a driver's workplace. On the other hand, a driver has limited cognitive resources to spare for additional information perception.

In this paper, a generic concept for automotive HMIs is developed, which acts as a coordination layer for independent running in-vehicle applications. The reference implementation was applied to the largest field operational test for V2X where over 30 parallel applications where evaluated in real traffic scenarios.

2 The sim^{TD} Project

The reference implementation of our HMI concept was applied to the largest field operational test for V2X, which was carried out in the project sim^{TD} (Safe and Intelligent Mobility – Test Field Germany). The consortium consists of major German car companies, suppliers, research institutes, and public institutions. Tests with a fleet of 120 cars are conducted in real traffic around the hessian metropolis Frankfurt/Main. The project will also pave the way for the political, economic and technological framework to successfully set up car-to-car and car-to-infrastructure networking.

As a member of the consortium, DFKI was responsible for the sim^{TD} Human Machine Interface (HMI), which presents information via a 7" center-stack display and audio channels. Besides V2X applications, drivers interact with an integrated navigation system and perform several tasks necessary in the field test, e.g. communicating with test operators via the HMI. Drivers are not only advised "experts" to the sim^{TD} system but also novices. Especially for this type of drivers it is of utmost importance that the Human Machine Interface (HMI) of the system is intuitive, non-distractive and features a consistent integration of all use-cases. The V2X use-cases evaluated can be classified into three categories: Safety, traffic efficiency, and value added services. Among these, there are local danger warnings (safety), traffic light optimal speed advisory (traffic efficiency) and parking information (value added services). Altogether, there are over 30 applications tested within the project. We refer the interested reader to the full list of selected functions in [3].

3 Intelligent Presentation Management for Automotive HMIs

3.1 General Overview

Applications initiate presentations by submitting *Presentation Requests*. These are validated against the corresponding *Presentation Model*, e.g. it is checked whether submitted values are within an allowed range. If this validation succeeds a Presentation

Task is created and stored in an internal database. The presentation component relies on time rather than spatial information and therefore possesses no situation knowledge. This means, that applications specify start and end time of a presentation and do not send distance information for presentation requests, e.g. *present in 2 seconds* rather than *present in 300m*. There exists a feedback channel to applications for notifying them of the current state of a Presentation Task during its lifecycle. During this lifecycle applications may request display space on the HMI. Because applications are running in parallel, conflicts are likely to occur. According to the current HMI context and priorities of the Presentation Tasks possible conflicts are resolved (cf. Section 3.6). When a task has been selected for presentation we use available *Display Strategies* defined in the Presentation Model in order to select presentation modality and -channel. The User Interface updates its state constantly after receiving new tasks. A synchronized communication ensures that the HMI is always assessing the current display context.

In the following the individual concepts of Presentation Models, Presentation Tasks, Display Strategies as well as conflict identification and resolution are further detailed.

3.2 Presentation Models

A Presentation Model contains essential information for a successful presentation on the HMI. The following list reflects all information that is part of such a Model:

- Id and Name
- Public interface: Specifies mandatory and optional parameters for this presentation
- Private parameters: Optional internal data for handling presentation tasks
- Display Strategies: Defines resources, that a task of this model occupies on the UI
- Automotive User Interface Markup Language (AUML): Communication protocol with the User Interface(s).
- Inheritance (see below)

A powerful feature of Presentation Models is the possibility for building up hierarchical structures. They inherit information (parts of the public interface, display strategies, etc.) from higher-ranking models. The top-level Presentation Model contains common parameters for all applications, e.g. start and end time of presentations. All others inherit this information reflecting the fact that start and end time are mandatory parameters for submitting Presentation Requests. Besides this, the top-level Presentation Model holds priority information, which is used for conflict resolution (c.f. Section 3.6). Fig. 1 shows a simplified version of Presentation Model inheritance for V2X-based local danger warnings. Every application type inherits from a higher-ranking model parameters *distanceToEvent* and *warningLevel*, which are common for all four Presentation Models *Obstacles on Road*, *Traffic Jam*, *Emergency Vehicle* and *Weather*. When necessary, the models specify application specific parameters, which are not shared among other models. Note, that in this simplified picture AUML is not included.

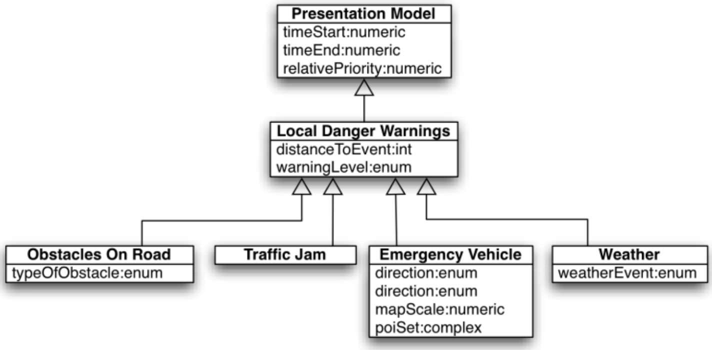

Fig. 1. Example inheritance for V2X-based local danger warnings

3.3 Parameter Types

Presentation Models offer the possibility to specify basic parameter type, e.g. numeric, or complex types similar to the type structure in higher programming languages. Every parameter specifies its name, type, valid domain (either as list or domain range) and an optional default value. Parameters not defining a default value are mandatory when requesting a presentation.

Complex types need internal processing before a Presentation Task can be displayed on the HMI. A practical example would be an application, which visualizes cars in transmission range on the display according to their relative position of the user's own car. Since the application possesses no knowledge about dimensions of its assigned drawing area on the HMI, it sends raw GPS coordinates in it Presentation Request. Before the Presentation Task is displayed or updated GPS coordinates are converted into screen coordinates. Complex types give application developers extra flexibility for preprocessing data before presentation.

3.4 Priority Concept

The priority concept is essential for resolving presentation conflicts. When developing V2X applications, every corresponding Presentation Model is assigned a *priority range* within the interval of (0,100) and a default priority. The application can vary current priority of a Presentation Task within this range using the parameter `relativePriority`, which is also inherited from the top-level Presentation Model. The priority range is not exposed directly to the application, rather than that a public parameter `relativePriority` is defined as (-100,100). This approach allows adapting model priorities without changing application code. A relative priority of 0 reflects the default priority of a model; all other values are mapped to the defined priority domain range. Priority ranges reflect the fact that importance of a Presentation Task is situation dependent, e.g. a warning before the end of a traffic jam ahead in 3 km might be lower in priority than a broken down vehicle right in front of the user's car. Within our HMI concept the assessment of such situations lies in responsibility of applications. On the other hand, applications do not possess any knowledge of HMI layout and structure. This separation of situation assessment and display management is essential for our HMI concept and is kept consistently throughout the components.

3.5 Automotive User Interface Language (AUML)

This section introduces the Automotive User Interface Markup Language (AUML) that enables communication with the User Interface and allocates interface resources for presentation. AUML is an XML-based communication protocol, which is tailored to automotive user interfaces. It is specified within Display Strategies of Presentation Models.

AUML knows *channels* and *layouts*. A channel is a communication interface with the user, e.g. visual or haptic. Furthermore, with the help of channels a communication interface can be modeled in detail in order to address sub-parts, e.g. a specific area on a display. Taxonomy of available channels is accessible throughout the framework. Channels (or parts of it) can be referenced within the Display Strategy section of a Presentation Model. Below channels in the AUML tree, layouts refer to UI implementations of applications. They can be addressed by their name or fully qualified class names and are loaded dynamically by the UI framework. Parameters and their current values necessary for presentation are contained in the layout part. Here, application specific parsing is required to instantiate and update the UI.

3.6 Conflict Identification and Resolution

Since all applications in the system are running independent from each other and possess no knowledge of HMI resources, presentation conflicts are possible. In order to realize the most efficient usage of the HMI the concept of Display Strategies is introduced. The AUML specified in Display Strategies define HMI resources an application occupies during presentation. Within one strategy several presentation channels can be specified, e.g. visual and auditory at the same time. The strategies are defined in the Presentation Model and are ordered in ascending priority.

An *Allocation Tree* is a hierarchical model of all available HMI resources (see Fig. 2). Every leaf in this tree resembles a channel and can be allocated by exactly one presentation task. Using *usability constraints* it is possible to restrict certain allocations. Considering the example tree in Fig.2 it is not possible to allocate the speakers by different Tasks, as this would degrade usability. HMI resources can be referenced within Display Strategies. Identifying presentation conflicts then boils down to comparing current allocation of the HMI and utilized resources of a Display Strategy, which has been selected for presentation.

When no conflict is detected, the first defined Display Strategy is selected. Conflict resolution is done by comparing priorities of both tasks and switching the lower prioritized presentation to its *alternative strategy*, if available. In cases where no conflict resolution can be identified either the application is notified about the aborted presentation or the presentation is postponed. Both are configurable fallback strategies.

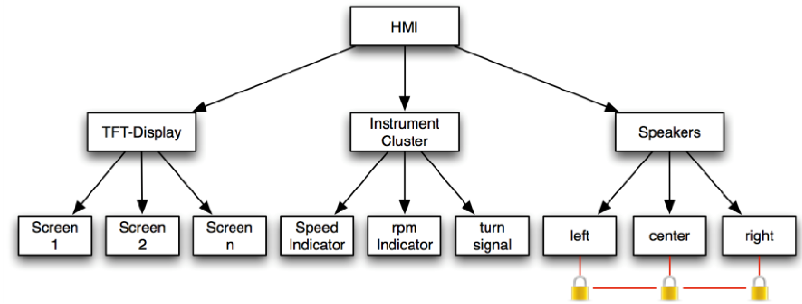

Fig. 2. A simple allocation tree. Locks symbolize usability constraints: These resources must not be allocated by different presentation tasks.

4 Reference Implementation: The sim^{TD} HMI

According to our generic HMI concept, we iteratively elaborated 34 Presentation Models for all sim^{TD} applications in agreement with the responsible application developers. For graphical representation on the touch display, we decided to create three virtual screens: Navigation, main, and option screen are arranged side-by-side and can be accessed using virtual buttons (see Figure 3).

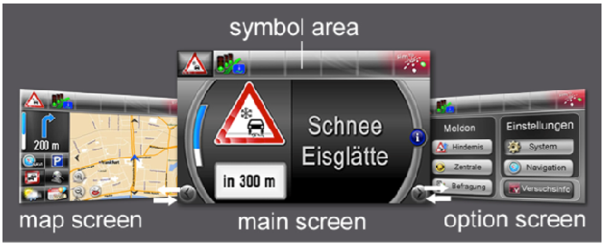

Fig. 3. Illustration of the sim^{TD} HMI depicting three virtual screens and symbol area

Most presentations request the main screen as their default presentation strategy. As on the main screen only one application can be presented at a time, we created a "symbol area", which is included on top of each screen. Hence, six additional slots for condensed presentations are available in the allocation tree and are part of alternative presentation strategies. Priority ranges have been defined and optimized for each application before the field test started. Our general HMI concept has been successfully applied to the sim^{TD} project. Currently, the HMI is running reliably in all 120 cars and test drivers are experiencing it on a daily basis.

5 Evaluation

Due to our intelligent presentation management concept, drivers only rarely have to interact with the sim^{TD} touch screen. However, interactions might be required from time to time, for example to switch a lower-priority function onto the main screen. Therefore, we measured its influence on driving performance in a safe driving simulation setup before admitting road usage. Above all, we wanted to test whether the sim^{TD} HMI fulfills two visual distraction criteria of [4].

*Participants***.** A total of 25 participants (14 females, 11 males) took part in our Experiment. Each of them was paid 10 Euros and their age ranged from 21 to 45 years. All participants had normal or corrected-to-normal vision and none of them reported any severe hearing problems. Due to eyetracker calibration problems for a few participants *n* was slightly reduced for some of the subsequent tests.

*Design***.** Each participant drove two tracks while interacting with the sim^{TD} system and one track while conducting a radio reference task. The order of conditions was counterbalanced between subjects (radio task during first, second, or third track). As a further factor, for 13 participants an instruction on the sim^{TD} system was presented before using it for the first time, whereas 12 participants encountered it only after the first sim^{TD} track and before the second sim^{TD} track. This was done orthogonally with respect to system presentation (order) to provide insights what influence a (missing) driver instruction would have on novice users.

*Materials***.** Participants were seated at a table with a steering wheel attached to it and pedals beneath (see Figure 4).

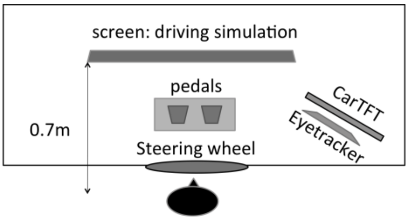

Fig. 4. Driving Simulation Setup

The driving simulation was displayed on a 24 inch screen at a distance of 0.7 meters. The sim^{TD} GUI was presented on a 7 inch touchscreen monitor, which was mounted on the table surface. An eyetracker was placed below this display to record drivers' glances.

As a primary driving task we used the lane change test [5] with participants driving on a straight three-lane road with 60 kilometers per hour. Each track lasts for about 3 minutes and 18 lane changes need to be conducted according to instructions presented on road signs.

During each track, participants completed radio tasks or sim^{TD} tasks. A set of 13 typical radio tasks like volume adjustment or to mute or to skip a song was provided by the experimenter and should be completed via an interface presented on the touchscreen (see Fig. 4). For each of the two sim^{TD} tracks 12 different tasks were provided like 'What temperature is expected in Saarbrücken this evening?' (navigation screen), 'Lost cargo on your route! In which distance will you encounter it?' (main screen), or

'You have spotted a deer close to the road: Send a local danger warning.' (option screen). By means of the system, participants could answer the questions or perform the actions required.

*Procedure***.** After completing an initial questionnaire participants made themselves familiar with the driving task in a practice drive. Subsequently, their driving performance for driving without a secondary task was recorded in a baseline drive followed by a general introduction into the sim^{TD} project and the goal of the experiment. As a next step the eyetracker was calibrated. Afterwards, each subject was driving 3 experimental tracks followed by another baseline drive at the end of the experiment. Regarding the experimental tracks participants were told to complete as many tasks as possible without adverse effects on driving performance. The experimenter took notes about task completion and accuracy (see Design for order of interaction conditions and timing of instructions). In the end participants completed a tailored questionnaire containing 5-point scales to rate usability of the sim^{TD} interface.

Dependent Variables and Hypotheses. We recorded and analyzed glance duration on the system screen, the number of tasks performed, task accuracy, system ratings, and driving performance.

- Glance duration onto the sim^{TD} screen does not exceed 2 seconds (85th percentile). Accumulated glance duration per task is below 20 seconds.
- Average gaze duration for sim^{TD} interaction does not exceed duration for radio interaction.
- Interacting with the sim^{TD} HMI does not affect driving performance more severely than radio interaction.
- Instructions improve sim^{TD} task performance.
- Interacting with the sim^{TD} system for the second time (after an initial 3-minutes interaction phase with similar tasks) leads to better task performance and driving performance.

5.1 Results and Discussion

For eye gaze behavior we found that even without prior system instructions, the 85th percentile of glance duration is far below 2 seconds (1.1 seconds for both sim^{TD} conditions and 1.0 seconds for the radio task). For mean accumulated gaze duration per task Helmert contrasts as part of a MANOVA revealed that this index was significantly lower in the second sim^{TD} track and the radio task compared with the first sim^{TD} drive ($F(1,20) = 15.71$, $p < .01$), and that the second sim^{TD} track still leads to larger accumulated gaze duration than the radio task ($F(1,20) = 57.50$, $p < .001$). Accordingly, sim^{TD} tasks on average lead to longer accumulated gaze distraction than simple radio tasks (they seem to be more complex), but this difference decreases significantly already with short training. In the first sim^{TD} track the 85th percentile of total glance time onto the display to perform a sim^{TD} task was quite long (25.2 seconds) and hence above the AAM guidelines' threshold of 20 seconds. In the second sim^{TD} track after instructions and a first system exploration in the first sim^{TD} track it was only 12.0 seconds and hence reduced drastically below threshold (7.6 seconds for radio tasks).

Task performance for the sim^{TD} system was investigated with instruction timing (before or after first usage) as an additional between subjects factor (see Table 1). A Helmert contrast as part of a repeated measures MANOVA revealed that in the second sim^{TD} drive significantly more tasks (mean 6.0) were completed than in the first drive (mean 3.4; radio mean 8.2), $F(1,24) = 14.04$, $p < .001$, $\eta^2 = .37$.

Table 1. Task performance. Upper value in cells: Number of tasks solved correctly (standard error); Lower value in cells: Corresponding number of erroneous/aborted tasks (standard error).

Instruction	Track1 sim^{TD}	Track 2 sim^{TD}
Before sim^{TD} track 1	4.2 (0.9)	5.4 (0.4)
	2.1 (0.5)	1.1 (0.3)
After sim^{TD} track 1	2.2 (0.7)	7.0 (0.8)
	2.9 (0.4)	0.9 (0.3)

Timing of instructions – before or after the first sim^{TD} track – interacted significantly with the number of tasks completed in sim^{TD} track 1 vs. 2, $F(1,23) = 8.13$, $p < .01$, $\eta^2 = 26$. For those subjects instructed before the first track, there is no significant increase in task performance between first and second track, $t(12) = 1.52$, $p = .15$. However, instructions presented only after the first track significantly increased performance for the second track for those participants, $t(11) = 4.65$, $p < .01$. Beyond underlining general effectiveness of instructions for the sim^{TD} system, these findings indicate that participants who were instructed later, even performed significantly more tasks successfully in the second track than those instructed earlier, $t(23) = 2.06$, $p < .05$, one-sided. Erroneous and aborted tasks reveal a consistent pattern. Effectiveness of instructions might be even increased if users can freely explore interactions beforehand – preparing the ground for mental models about the system. Instructions might thus rather bear fruit than pure theoretical instructions prior to exploration.

A repeated measures MANOVA revealed differences in driving performance caused by task type, $F(1,23) = 8.13$, $p < .01$, $\eta^2 = 26$. Pairwise comparisons (Bonferroni corrected) revealed that driving was significantly worse in the first sim^{TD} drive (mean deviation 1.66) compared with both the radio task (mean deviation 1.36, $p < .01$) and the second sim^{TD} drive (mean deviation 1.46, $p < .05$). The difference of the second sim^{TD} drive and the radio task drive was far from significant. Hence, after an instruction and a short practice period driving performance while interacting with the sim^{TD} system seems to remain similar to a radio reference task and is hence tolerable.

Seven out of eight ratings about the system (e.g. graphical quality, navigation in system, understandability, self-descriptiveness) on a symmetric scale from '1 - do not agree' to '5 – strongly agree' were significantly above average ($t > 2.6$, $p < .05$). Only information accessibility was not significantly rated above average (3.48, $t = 1.88$, *n.s.*). This weakness might be tolerable, as most of the screen area is reserved for system-initiated information presentation, which automatically reduces space for buttons and hence leads to deeper menu structures. Moreover, some experimental tasks like finding out prices for event tickets were located deeper in menu structures as they are supposed to occur very rarely.

6 Summary and Conclusions

Our automotive HMI concept enables intelligent and situation-adaptive presentation management leading to less driver-initiated interaction and therefore less driver distraction. Due to its generic nature, the concept can be applied to all cases in which ADAS and/or IVIS need to be coordinated. In cases when a driver still needs to manually interact with the sim^{TD} system, she is still able to drive safely (glance duration, total glance time, driving performance) and participants confirmed overall system usability in questionnaires. In a nutshell, interaction affordances possibly generated by our HMI approach do not exceed a critical level. Moreover, the better presentation management is adjusted, the less frequently manual interactions need to be performed. Nevertheless, instructions and a brief practice period are advisable for such complex system as they enhance performance and reduce driver distraction. These findings are currently taken into account in the field test.

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Proposal of Non-dimensional Parameter Indices to Evaluate Safe Driving Behavior

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Abstract. Our previous study proposed Deceleration for Collision Avoidance (DCA) as an new index for use when evaluating collision risk against forward obstacles. The present manuscript proposes four non-dimensional parameter indices which are based mainly on the DCA, in order to provide quantitative assessment of safe driving behavior. Numerical simulations are performed to verify validity of the proposed indices.

Keywords: safe driving evaluation system, deceleration for collision avoidance, driving behavior.

1 Introduction

Our previous studies proposed Deceleration for Collision Avoidance (DCA) as an index to define a warning provision threshold [1,2] and examined that a Forward Obstacles Collision Warning System (FOCWS) based on the DCA was effective to enhance driver's situation awareness [3].

Meanwhile, there is a psychological theory, called "*a risk homeostasis theory*" [4], which argues that a long-term effectiveness of various kinds of driver-assistance systems will decrease because of driver's risk compensation behavior. In other words, a driver who feels the driving situation became safer tends to convert a margin gained by the driver-assistance system to improvement of his/her driving efficiency.

The driving simulator experiments of our previous study [5] suggested that a presentation of a fuel-consumption meter would improve driver's motivation for fuel-efficient driving and secondarily it would prevent the risk compensation behavior while the safer driving was derived from only the side-effect of fuel-efficient driving. Therefore, a final goal of this study is to construct a safe driving evaluation system (SDES) to encourage drivers to perform safe driving directly by a feedback of safe driving evaluation results. As the first step, the present study proposes four evaluation indices to provide quantitative assessment of safe driving, and performes numerical simulations to verify validity of the indices.

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 470–479, 2013.

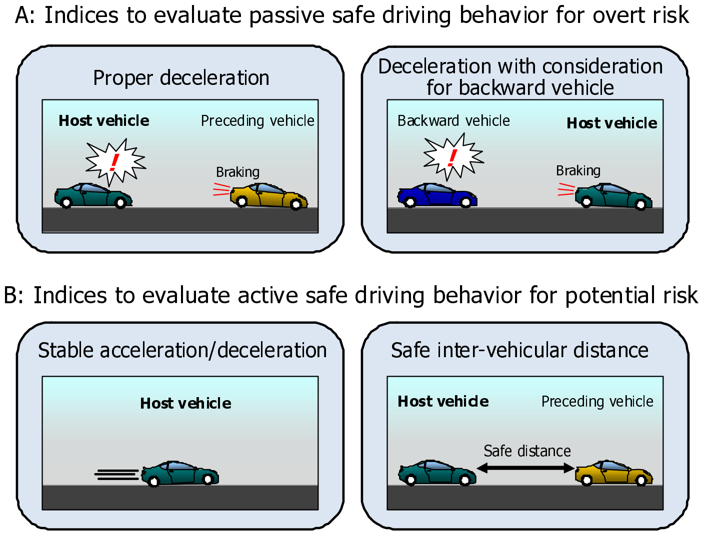

Fig. 1. Four indices to evaluate safe driving behavior. (upper) Two indicies to evaluate passive safe driving behavior for overt risk. (lower) Two indicies to evaluate active safe driving behavior for potential risk.

2 Four Types of Evaluation Indices

2.1 Deceleration for Collision Avoidance (DCA)

The DCA represents a minimum required deceleration of a host vehicle (HV) necessary to avoid a collision against a forward obstacle such as a preceding vehicle (PV) and a pedestrian [1,2]. There are two types of DCAs: a DCA in a situation where the PV maintains its current acceleration is defined as an overt DCA (ODCA), and a DCA that is based on the assumption that the PV will decelerate abruptly at any moment is defined as a potential DCA (PDCA). A driver can understand proper avoidance action to take when the DCA value is presented, because it has a strong correlation with the amount of driver's brake pedal depression.

Adequacy of deceleration maneuver can be evaluated by comparison of ODCA and actual deceleration of the HV. ODCA represents an overt collision risk based on a relative relationship between the HV and the PV. Moreover, application of ODCA to a relative relationship between a backward vehicle (BV) and the HV can yield estimation of a collision risk of the HV against the BV. Hence, the present study calculates a longitudinal overt collision risk from a viewpoint of acceleration (deceleration) by using the ODCA in order to evaluate adequacy of driver's maneuver against the overt risk.

2.2 Indices to Evaluate Passive Safe Driving Behavior for Overt Risk

A state where an overt collision risk from the HV to the PV exists is defined to be equivalent to a state where the HV has to decelerate at more than a constant value in order to avoid a collision against the PV. Moreover, a state where an overt risk from the HV to the BV exists is defined as a state where the BV has to decelerate at more than a constant value in order to avoid a collision against the HV. Consequently, the present study proposes two indices to evaluate passive safe driving behavior for overt risk objectively; *proper deceleration* (I_F) and *deceleration with consideration for BV* (I_B) (upper figures of Fig. 1).

Index I: Proper Deceleration (I_F). A driver of the HV has to decelerate at more than the ODCA value immediately when an overt collision risk such as abrupt deceleration of the PV appears. If a significant delay occurs in the HV driver's reaction or a deceleration in the early phase of the reaction is not enough, a large deceleration must be required after the avoidance maneuver starts. Therefore, an index I_F is defined as a ratio of the actual acceleration of the HV divided by the ODCA.

A following function $f_e(t)$ represents whether or not the overt risk appears, in other words, the current situation should be evaluated or not.

$$f_e(t) = \begin{cases} 1 \ (\alpha_{o,f} > \theta_{o,f}, \quad t > t_f + T_{r,f}(t_f)) \\ 0 \qquad\qquad\qquad \text{else} \end{cases} \tag{1}$$

where $\alpha_{o,f}(\geq 0)[\mathrm{m/s^2}]$ is an ODCA value of the HV to the PV, $\theta_{o,f}(> 0)[\mathrm{m/s^2}]$ is a constant threshold, t_f is a time when $\alpha_{o,f}$ exceeds $\theta_{o,f}$, and $T_{r,f}(t_f)[\mathrm{s}]$ is an assumed HV driver's reaction time.

Equation $f_e(t) = 1$ defines "*a state where an overt risk occurs*" as a state where $\alpha_{o,f}$ is still larger than $\theta_{o,f}$ even after the driver's reaction time $T_{r,f}$ passed from the moment when the ODCA value $\alpha_{o,f}$ exceeds the theleshold $\theta_{o,f}$.

Appropriateness $f(t)$ of deceleration behavior at time t is defined by

$$f(t) = f_e(t) \times \begin{cases} 1 \qquad (d_f > \alpha_{o,f}, \quad \alpha_{o,f} \leq d_{f,max}) \\ \dfrac{d_f}{\alpha_{o,f}} \ (\alpha_{o,f} \geq d_f \geq 0, \ \alpha_{o,f} \leq d_{f,max}) \\ 0 \qquad\qquad\qquad \text{else} \end{cases} \tag{2}$$

where $d_f[\mathrm{m/s^2}]$ denotes an actual deceleration of the HV, and $d_{f,max}$ is an assumed maximum deceleration of the HV.

Equation (2) represents that the function $f(t)$ expresses a ratio of the actual deceleration of the HV to the ODCA value in a situation where the overt risk occurs. It also denotes that the deceleration behavior is more proper when the ratio comes closer to one and conversely it is more improper when the ratio comes closer to zero. Note that $f(t)$ becomes zero in the following three cases; 1) an overt risk does not occur ($f_e(t) = 0$), 2) the HV does not decelerate ($d_f \leq 0$), or 3) an ODCA value exceeds the maximum decelertaion ($\alpha_{o,f} > d_{f,max}$).

Time integral of $f_e(\tau)$ of Eq. (1) from 0 to t describes a summation of evaluation time, and it is expressed by $T_f(t)$. Here, an index $I_F(t)$ is defined by the following equation.

$$I_F(t) = \frac{\int_0^t f(\tau)d\tau}{\int_0^t f_e(\tau)d\tau} = \frac{\int_0^t f(\tau)d\tau}{T_f(t)} \tag{3}$$

Note the index $I_F(t)$ is defined to be zero when $T_f(t)$ is zero.

The index $I_F(t)$ is a non-dimensional parameter varied from 0 to 1, and it denotes an average value of adequacy of deceleration behavior in a time range from 0 to t. Accordingly, when $T_f(t) > 0$ and $I_F(t)$ comes closer to one, the driver's deceleration behavior is evaluated to be more proper against the overt risk occurred in front of the HV.

Index II: Deceleration with Consideration for Backward Vehicle (I_B). When the HV decelerates abruptly, a driver of the BV has to decelerate at more than a minimum required deceleration in order to avoid a collision. It means that the deceleration of the HV might cause an overt collision risk of the BV. If the inter-vehicular distance is short or the avoidance action of the BV is delayed because of the driver's distraction and so on, the collision risk will be increased. In other words, the BV cannot decelerate properly when the HV decelerates without consideration for the BV. Consequently, an index I_B is defined as a ratio of the actual acceleration of the BV divided by its ODCA.

By substitutions of PV to HV and HV to BV in a relationship mentioned in "Index I: Proper deceleration (I_F)", adequacy of the BV's deceleration behavior against the HV in a time range from 0 to t can be expressed by

$$I_B(t) = \frac{\int_0^t b(\tau)d\tau}{\int_0^t b_e(\tau)d\tau} = \frac{\int_0^t b(\tau)d\tau}{T_b(t)}. \tag{4}$$

Functions $b_e(t)$ and $b(t)$ are defined by

$$b_e(t) = \begin{cases} 1 \ (\alpha_{o,b} > \theta_{o,b}, \quad t > t_b + T_{r,b}(t_b)) \\ 0 \qquad\qquad\qquad \text{else} \end{cases} \tag{5}$$

$$b(t) = b_e(t) \times \begin{cases} 1 & (d_b > \alpha_{o,b}, \quad \alpha_{o,b} \leq d_{b,max}) \\ \dfrac{d_b}{\alpha_{o,b}} & (\alpha_{o,b} \geq d_b \geq 0, \ \alpha_{o,b} \leq d_{b,max}) \\ 0 & \text{else} \end{cases} \tag{6}$$

where $\alpha_{o,b}(\geq 0)$ is an ODCA value from the BV to the HV, t_b is a time when $\alpha_{o,b}$ exceeds a constant threshold $\theta_{o,b}$, $T_{r,b}(t_b)$ is an assumed the BV driver's reaction time, d_b is an actual deceleration of the BV, and $d_{b,max}$ is an assumed maximum deceleration of the BV.

3 Indices to Evaluate Active Safe Driving Behavior for Potential Risk

We define a state where the risk is potential as a state where an overt risk does not occur in a longitudinal direction of the HV (e.g., there is no obstacle, or the HV follows the PV which runs at a constant velocity). In order to respond adequately to the overt risk, it is desirable to take safer driving behavior in a preventive manner from a stage when a collision risk is still potential. The present study, therefore, proposed two indices to evaluate passive safe driving behavior for overt risk objectively; *stable acceleration/deceleration* (I_A) based on the actual acceleration of the HV, and *safe inter-vehicular distance* (I_D) based on the PDCA (lower figures of Fig. 1).

Index III: Stable Acceleration/Deceleration (I_A). Stability of the HV must be ensured in order to perform proper avoidance maneuver when the overt risk occurs. For example, if the driver accelerates or decelerates roughly on a slippery road such as packed snow road, it is difficult to respond to the overt risk because a sideslip will happen. Accordingly, it is valid to employ the index which can represent whether the driver performed reasonable maneuver. That is to say, an index I_A is defined by a ratio of the actual acceleration to the order acceleration and it can evaluate an adequacy of the acceleration maneuver.

Based on the concept, the adequacy $I_A(t)$ of the acceleration maneuver in a time range from 0 to t is expressed as follows.

$$I_A(t) = \frac{\int_0^t a(\tau)d\tau}{\int_0^t a_e(\tau)d\tau} = \frac{\int_0^t a(\tau)d\tau}{T_a(t)} \tag{7}$$

The functions $a_e(t)$ and $a(t)$ are defined by

$$a_e(t) = \begin{cases} 1 \ (v_f > 0, \quad |a_i| > \theta_a) \\ 0 \qquad\qquad \text{else} \end{cases} \tag{8}$$

$$a(t) = a_e(t) \times \begin{cases} 1 & \left(1 < \frac{a_f}{a_i}\right) \\ \dfrac{a_f}{a_i} & \left(0 \leq \frac{a_f}{a_i} \leq 1\right) \\ 0 & \left(\frac{a_f}{a_i} < 0\right) \end{cases} \tag{9}$$

where v_f[m/s] and a_f[m/s^2] represent the HV's velocity and acceleration, $\theta_a(> 0)$ [m/s^2] is a constant threshold, and a_i[m/s^2] is acceleration order value input by a gas pedal and a brake pedal.

The index I_A has a similarity with the above-mentioned two indices I_F and I_B in the point where all of them are non-dimensional parameters based on acceleration to evaluate adequacy of driving behavior although I_A does not employ the the DCA unlike with other two indices.

Index IV: Safe Inter-vehicular Distance (I_D). If the PV decelerates abruptly in a case of short inter-vehicular distance, the HV has to perform a hard braking because of the driver's response lag. Conversely, in a case of long inter-vehicular distance, a possibility to take proper avoidance action against the forward overt risk will be increased. The present paper proposes an index I_B to evaluate adequacy of the inter-vehicular distance by using score from 0 to 1 which is calculated based on the PDCA value.

PDCA is a minimum required deceleration of the HV to avoid a collision on the assumption that the PV will decelerate at 0.6[G] at any moment. The PDCA value becomes smaller according to wider inter-vehicular distance [1,2], and then the present study propses an index to evaluate adequacy of the inter-vehicular dinstance by using the PDCA.

Similarly with other three indices, an adequacy $I_D(t)$ of the inter-vehicular distance in a time range from 0 to t is expressed as the following ratio.

$$I_D(t) = \frac{\int_0^t d(\tau)d\tau}{\int_0^t d_e(\tau)d\tau} = \frac{\int_0^t d(\tau)d\tau}{T_d(t)} \tag{10}$$

A function $d_e(t)$ is defined by

$$d_e(t) = \begin{cases} 1 \ (\alpha_{p,f} > \theta_{p,f}, \ \alpha_{o,f} \leq \theta_{o,f}, \ v_p > 0) \\ 0 \qquad\qquad\qquad \text{else} \end{cases} \tag{11}$$

where v_p is the PV's velocity, $\alpha_{p,f}(\geq 0)[\text{m/s}^2]$ is a PDCA value from the HV to the PV, and $\theta_{p,f}(> 0)[\text{m/s}^2]$ is a constant thresholdDInequality $\alpha_{p,f} > \theta_{p,f}$ represents a situation where the HV follows the PV, and inequality $\alpha_{o,f} > \theta_{o,f}$ represents a situation where a collision risk becomes overt. Note that the index I_D is not evaluated in the latter case.

This manuscript defines a function $d(t)$ with respect to the PDCA as follows.

$$d(t) = d_e(t) \times \begin{cases} 1 & (\alpha_{p,f} < \theta^-_{p,f}) \\ \dfrac{\theta^+_{p,f} - \alpha_{p,f}}{\theta^+_{p,f} - \theta^-_{p,f}} & (\theta^-_{p,f} \leq \alpha_{p,f} \leq \theta^+_{p,f}) \\ 0 & (\theta^+_{p,f} < \alpha_{p,f}) \end{cases} \tag{12}$$

where $\theta^+_{p,f} > \theta^-_{p,f}(> \theta_{p,f})[\text{m/s}^2]$ are upper and lower constant thresholds. As shown in Eq. (12), the function $d(t)$ becomes one when the PDCA value $\alpha_{p,f}$ is smaller than $\theta^-_{p,f}$, it becomes zero when $\alpha_{p,f}$ is larger than $\theta^+_{p,f}$, and it changes linearly in a range $\theta^-_{p,f} \leq \alpha_{p,f} \leq \theta^+_{p,f}$.

The evaluation index I_D of Eq. (10), therefore, becomes higher when the PDCA value $\alpha_{p,f}$ is smaller (e.g., the inter-vehicular distance is longer).

4 Numerical Simulations

The positions, velocities, and accelerations of HV, PV, BV are defined as x_f, v_f, a_f, x_p, v_p, a_p, x_b, v_b, a_b, respectively, and the relative positions between PV

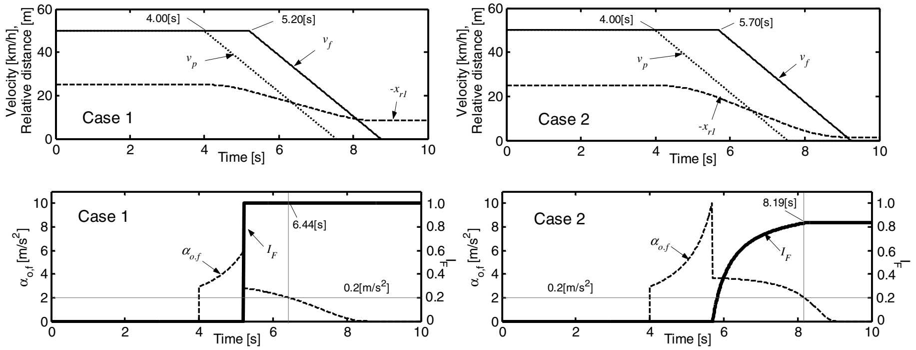

Fig. 2. Simulation results of Index I: Proper deceleration: (upper) Velocities of HV and PV, and inter-vehicular distance (left: Case 1, right: Case 2), (lower) Time series data of ODCA value $\alpha_{o,f}$ and Index value I_F (left: Case 1, right: Case 2).

and HV, HV and BV are defined as x_{r1} and x_{r2}. Note that the relative poisions $x_{r1}(= x_f - x_p)$, $x_{r2}(= x_b - x_f)$ become negative when the HV (BV) follows the PV (HV) from behind. The inter-vehicular distance can be calculated by multiplying the relative distances x_{r1}, x_{r2} by minus [6].

In this simulation, the constant variables necessary to calculate the four indicies are defined as follows; $\theta_{o,f} = \theta_{p,f} = 2.0[\text{m/s}^2]\text{C}\theta_a = 0.5[\text{m/s}^2]\text{C}\theta^-_{p,f} = 4.0[\text{m/s}^2]$, $\theta^+_{p,f} = 8.0[\text{m/s}^2]$, and $d_{f,max} = d_{b,max} = 6.0[\text{m/s}^2]$.

4.1 Proper Deceleration (I_F)

Here, assume a situation where the PV performs abrupt deceleration when the HV follows the PV. Upper figures of Fig. 2 illustrate velocities v_p, v_f and the inter-vehicular distance $-x_r$. The PV decelerates at 3.92[m/s^2] (=0.4[G]) after a following state where $v_p = v_f = 50$[km/h] and $-x_{r1} = 25$[m], and then, the HV starts to decelerate 1.2[s] (Case 1) or 1.7[s] (Case 2) after the PV's deceleration.

Lower figures of Fig. 2 show the time series data of ODCA value $\alpha_{o,f}$ and the index I_F which evaluates adequacy of the deceleration behavior. The ODCA value exceeds the threshold $\theta_{o,f} = 2.0[\text{m/s}^2]$ at 4.0[s] when the PV starts to decelerate, and therefore, the index I_F is evaluated from 5.2[s], which is a moment the assumed driver's reaction time (=1.2[s]) passes. In the Case 1 where the HV decelerates in the assumed reaction time, the ODCA value is decreased at a moment when the HV starts to decelerate and it falls below $\theta_{o,f} = 2.0[\text{m/s}^2]$ at 6.44[s]. Namely, the overt risk occurs from 5.2[s] to 6.44[s], and the lower-left figure of Fig. 2 shows that the ODCA value is smaller than the HV's actual deceleration 0.4[G] during that time. Therefore, the index I_F which is the average value of $f(t)$ during the evaluation time maintains a perfect score.

Next, let us consider the Case 2 where the HV decelerates in 1.7[s] which is behind the assumed reaction time. The index I_F maintains zero from 5.2[s] to 5.7[s] because $f(t)$ becomes zero. After the HV decelerates, I_F is increased

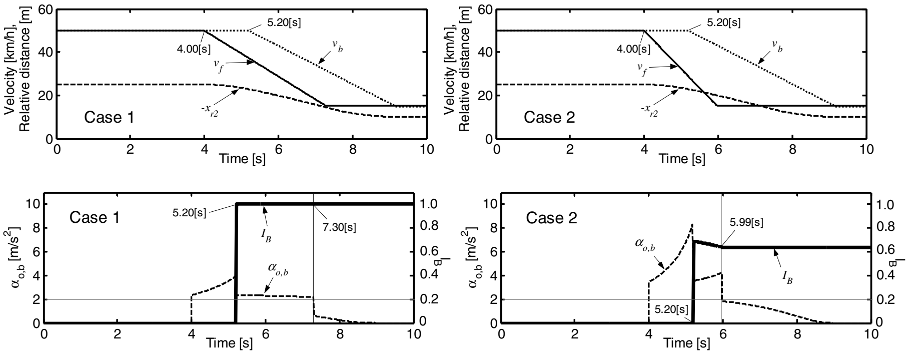

Fig. 3. Simulation results of Index II: Deceleration with consideration for BV: (upper) Velocities of BV, HV, and inter-vehicular distance (left: Case 1, right: Case 2), (lower) Time series data of ODCA value $\alpha_{o,b}$ and Index value I_B (left: Case 1, right: Case 2).

because $f(t)$ becomes one. The evaluation is terminated at 8.19[s] when the ODCA value becomes smaller than 2.0[m/s^2], and finally the index I_F becomes 0.83.

In the Case 1 where the HV performs necessary deceleration to avoid collision against the PV immediately, the evaluation score becomes higher than that in the Case 2. Consequently, the simulation results suggest that the index I_F can evaluate the adequacy of the deceleration behavior.

4.2 Deceleration with Consideration for Backward Vehicle (I_B)

Assume that the BV follows the FV from behind as shown in upper figures of Fig. 3. The FV decelerates at two types of deceleration at 4.0[s]; Case 1: 2.94[m/s^2] (=0.3[G]) and Case 2: 4.9[m/s^2] (=0.5[G]), and the BV decelerates at 2.45[m/s^2] (=0.25[G]) 1.2[s] after the FV's deceleration.

The lower figures of Fig. 3 illustrate the transitions of the BV's ODCA value ($\alpha_{o,b}$) and the index I_B. Similarly with the index I_F of the Case 1 as mentioned in 4.1, the index I_B of the Case 1 becomes one because $b(t) = 1$ is satisfied for all evaluation time. In the Case 2, the index I_B finally becomes 0.64 because the BV's actual deceleration (=0.25[G]) is lower than $\alpha_{o,b}$ for evaluation time between 5.2[s] and 5.99[s].

The evaluation index I_B in the Case 1 where the HV decelerates gently becomes higher than that in the Case 2 where the HV performs abrupt deceleration. Therefore the simulation results represents the validity of I_B.

4.3 Stable Acceleration/Deceleration (I_A)

Let us consider a situation where the HV decelerates on a slippery road whose road surface friction coefficient is 0.2 (upper figures of Fig. 4).

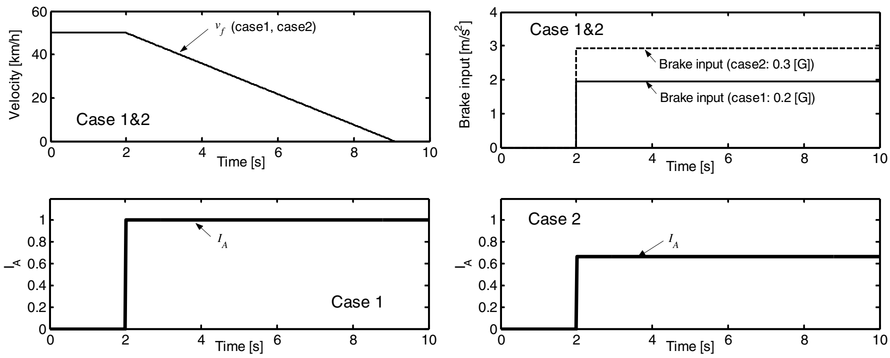

Fig. 4. Simulation results of Index III: Stable acceleration/deceleration: (upper-left) Velocities of HV (Cases 1&2), (upper-right) Brake inputs of HV (Cases 1&2). (lower) Time series data of Index value I_A (left: Case 1, right: Case 2).

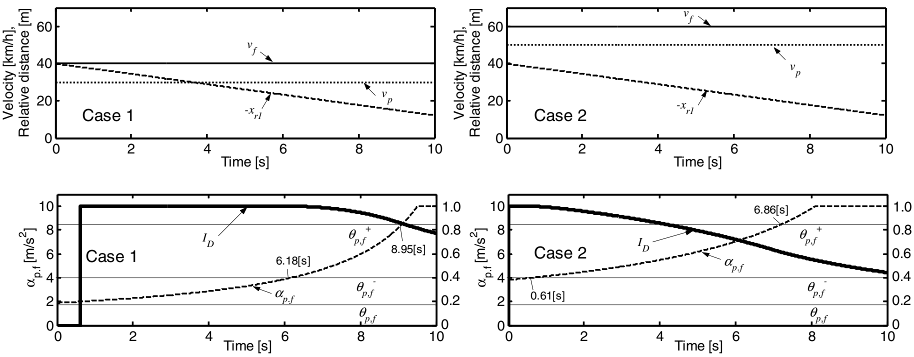

Fig. 5. Simulation results of Index IV: Safe inter-vehicular distance: (upper) Velocities of HV and PV, and inter-vehicular distance (left: Case 1, right: Case 2), (lower) Time series data of PDCA value $\alpha_{p,f}$ and Index value I_D (left: Case 1, right: Case 2).

The index value I_A keeps a perfect score in the Case 1 where the driver of the HV inputs a proper deceleration order (a_i=0.2[G]) in consideration of the road condition. On the other hand, the index value I_A becomes lower (0.67) in the Case 2 where the driver inputs a danger deceleration order (a_i=0.3[G]) which exceeds the road surface friction coefficient.

4.4 Safe Inter-Vehicular Distance (I_D)

This subsection assumes two types of following situations; an initial inter-vehicular distance is 40[m] and a relative velocity is 10[km/h] where initial velocities of the Case 1 are (v_p, v_f)=(30, 40) and those of Case 2 are (v_p, v_f)=(50, 60), as shown in upper figures of Fig. 5.

The lower figures of Fig. 5 show transitions of the FV's PDCA value ($\alpha_{p,f}$) for the PV and the index I_D. In both cases, evaluation is started at a moment when $\alpha_{p,f}$ exceeds the threshold $\theta_{p,f} = 2.0[\text{m/s}^2]$, and the score of I_D begins to decrease when $\alpha_{p,f}$ exceeds $\theta^-_{p,f} = 4.0[\text{m/s}^2]$. The value of $d(t)$ becomes smaller as increasing $\alpha_{p,f}$, and it becomes zero when $\alpha_{p,f}$ exceeds $\theta^+_{p,f} = 8.0[\text{m/s}^2]$. Comparison of lower figures of Fig. 5 shows that the I_D becomes higher in the case of lower velocity even if the relative inter-vehicular distance and the relative velocity are same. In other words, the simulation results indicate that the index I_D can evaluate safe driving behavior properly according to the difference of velocity.

5 Conclusions

The present manuscript proposed four indices to evaluate longitudinal driving behavior; *proper deceleration* (I_F) and *deceleration with consideration for backward vehicle* (I_B) in the situation when the overt collision risks occur, and *stable acceleration/deceleration* (I_A) and *safe inter-vehiclular distance* (I_D) in the situation when the overt risks do not occur. The four indices are non-dimensional parameter based on acceleration (deceleration). Moreover, numerical simulations indicated that these indices could evaluatesafe driving behavior properly.

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Autonomous Locomotion Based on Interpersonal Contexts of Pedestrian Areas for Intelligent Powered Wheelchair

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Abstract. In a rapidly aged society, providing mobility aids such as motorized wheelchairs is becoming increasingly important. Although such mobility aids have recently been developed with autonomous locomotion functions, their technologies and locomotive styles are basically based on unmanned vehicles, not on welfare mobility aids. In order to realize harmonious autonomous locomotion, this research proposed the concept of "Interpersonal Contexts on pedestrian areas", and developed prototype technologies utilizing the contexts: velocity control based on interaction prediction of surrounding pedestrians, and interactive collision avoidance based on surrounding mobility type. This paper explains briefly their functions and results, and discussed their utilities based on the interpersonal contexts.

Keywords: Autonomous Vehicle, Human-Machine Collaboration, Collision Avoidance, Interactive Safety.

1 Introduction

1.1 Motivation

Since Japan has become a Super Aged Society, enabling the elderly's continued mobility to allow for outings is a major issue that is closely related to the maintenance of health. Electric powered mobility devices can help the elderly who have difficulty walking and participating in social activities. For the elderly who have decreased locomotive abilities, various types of mobility scooters have been developed. However, decreased cognitive abilities and judgment as a result of aging sometimes make it impossible for users of mobility aids to drive, even if they could drive previously. For such aged users, intelligent mobility aids which have functions of autonomous locomotion can be helpful.

1.2 Existing Technologies of Autonomous Locomotion

For autonomous vehicles moving in the crowded pedestrian areas, not colliding with other traffic participants is important. Researches in the field of mobile robots have

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 480–489, 2013.

contributed developments of algorithms of collision avoidance. For example, Khatib[1] proposed Potential Field Method, which steered mobile robots based on the artificial potential. Similarly, Fox et al.[2] developed Dynamic Window Method. These methods were designed for the mobile robots in relatively static situations. After these pioneer researches, various methods for collision avoidance have been developed. Since the desired fields where robots were desired to be utilized had spread into our living environment, much more dynamic methods of collision avoidance became necessary. Human-symbiotic robot "EMIEW" developed by Hosoda et al.[3] achieved collision-free locomotion based on sensing and prediction of velocities of surrounding traffic participants. As these researches achieved, technologies of collision-free autonomous locomotion were realized at a certain level. However, many existing studies focused mainly on numerical algorithms of collision avoidance, and not on styles of autonomous locomotion. They developed avoiding algorithms basically based on only physical indices such as proximity, direction and relative velocity between obstacles and mobile robots. Some researches considered autonomous locomotion as continued avoidances for the pedestrians, who were substitutions of obstacles. Other researches realized the autonomous locomotion by always stopping the vehicle in front of pedestrians. This research thought that such uniform styles of collision avoidance were not always effective for harmonious autonomous locomotion, which was safe, smooth and acceptable locomotion in other words. Therefore, this research proposed and developed functions of harmonious autonomous locomotion based on "Interpersonal Contexts", which enabled intelligent mobility aids to interact with other traffic participants.

2 Concepts of Harmonious Autonomous Locomotion Based on Interpersonal Contexts

2.1 Necessary Requirements for Harmonious Locomotion on Pedestrian Areas

Generally speaking, safe locomotion is different from smooth and acceptable locomotion; further, smooth locomotion is different from acceptable locomotion. Fig. 1 shows our concept of hierarchical characteristics of harmonious locomotion, which is applied to not only autonomous locomotion but also human-operated locomotion. For realizing safe locomotion, vehicles have only to avoid collisions. Unmanned carts in automated factories, which do not need smooth and acceptable locomotion, are typical examples of this category. For realizing smooth locomotion, vehicles have to move with soft velocity, acceleration and yaw rate. On the contrary, for realizing acceptable locomotion, vehicles have to move by considering either rules or contexts. Automobiles and welfare mobility aids are examples of these categories. Publicness of locomotion environment divides these categories: welfare mobility aids on private areas need only smooth locomotion, and those on public aresa need acceptable locomotion. On these points, harmonious autonomous locomotion of welfare mobility aids is not realized only by the exiting robotic technologies, which have already realized smooth autonomous locomotion.

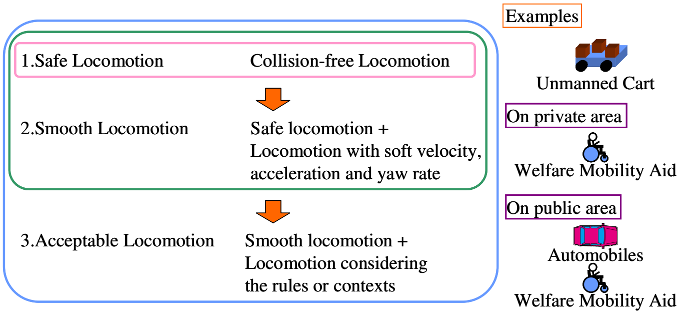

Fig. 1. Hierarchical Characteristics of Harmonious Locomotion

Fig. 2 shows the appearance of a typical sidewalk, which is our target locomotion environment. Pedestrians, wheelchair users, mobility scoter users, and bicycle riders travel on common sidewalks, although bicycle riders have limited permission for most areas. Because their locomotion velocities vary widely as shown in Fig. 3, interactions such as overtaking by changing lanes, making a sufficient margin for safely overtaken, and avoiding oncoming traffic participants, happen very often. In addition, there are no defined rules for such interactions in this environment. Thus, contexts are the dominant factor of the acceptability of locomotion on pedestrian area. The lack of the rule and existence of ambient contexts are discriminative differences from the cases of other vehicles. On this point, Fig. 4 shows characteristics of locomotion that was considered in this research. For example, locomotion of trains on railways is the typical example of the most rule-based locomotion. On the other hand, locomotion of welfare mobility aids on pedestrian areas is that of the most context-based locomotion. Locomotion of automobiles in public roadway is partly rule-based and partly context-based.

Because the rule of locomotion is not obvious, traffic participants on pedestrian areas need to share contexts for the harmonious locomotion. Likewise, even intelligent mobility aids need to share contexts. In other words, intelligent mobility aids should become not a special machine but a usual traffic participant on pedestrian areas. In this situation, usual traffic participants pay attention to other traffic participants for harmonious locomotion. They confirm not only positions and velocities of surrounding traffic participants but also characteristics of them. In addition, they evaluate

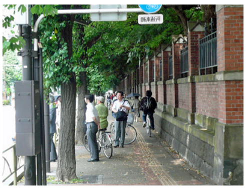

Fig. 2. Appearance of Target Locomotion Environment (Left side)

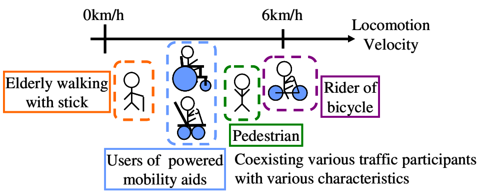

Fig. 3. Locomotion Velocities according to Mobility Type of Traffic Participants (Right side)

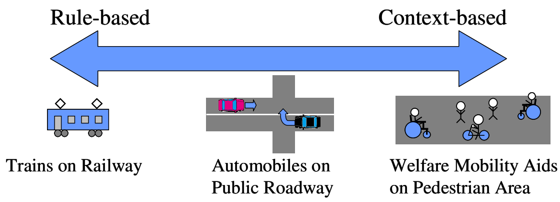

Fig. 4. Characteristics of Locomotion from the Aspect of Dominant Factor of Acceptability

near-future traffic situations as well as current ones. Moreover, evaluation criteria for such information change according to contexts. This research thought that the management of such information about surrounding traffics seemed the key of harmonious locomotion; besides, this research defined those kinds of information as "Contexts on pedestrian areas". Furthermore, this research thought that harmonious autonomous locomotion of intelligent mobility aids would be realized by developing the recognition system of contexts on pedestrian area.

2.2 Various Contexts on Pedestrian Areas

There are various kinds of contexts on pedestrian areas. For example, pedestrians change locomotion path suddenly if there are some attractive stores on their way. In another situation, traffic participants change their locomotive velocities if the climate changes suddenly. In the situations of some disasters, traffic participants change their locomotion styles from a normal locomotion to an emergency escape. This research thought that these examples were all contextual locomotion: the first one was an example of place-based context, the second one was that of climate-based context, and the third one was that of emergency-based context. Thinking of and sharing these contexts is necessary to realize the harmonious locomotion.

Some of existing researches developed the technologies for autonomous locomotion partly based on contexts, although they did not mention the concept of contexts. For example, Ohki et al. [4] developed a collision avoidance method for rescue robots. Their method utilized an emergency-based context and realized prediction of pedestrians' locomotion in a panicked state. As this research realized, autonomous locomotion considering the contexts would be useful.

2.3 Interpersonal Contexts for Autonomous Locomotion on Pedestrian Areas

Most of existing researches of intelligent mobility aids proposed algorithms of autonomous locomotion based on technologies of unmanned vehicle; they considered surrounding objects as obstacles. However, this assumption is not true because surrounding objects on pedestrian areas are not obstacles but other traffic participants. Moreover, intelligent mobility aids are not an unmanned vehicle but welfare vehicles which someone rides on. On this point, assumption and information used for existing intelligent mobility aids have not been fitted to situations of the real world. Thus, interpersonal contexts are much more necessary for harmonious autonomous locomotion of welfare mobility aids. For the welfare mobility aids which someone ride on, not only physical aspects of locomotion such as acceptable acceleration and velocity but also emotional and psychological aspects should be considered in order to improve acceptability of locomotion.

For example, although excessively safe styles such as always stopping the vehicle in front of other traffic participants without considering contexts could realize collision-free locomotion, it would give the diffident feeling to the riders. Since the purpose of this research is to realize continuous outings of the elderly by the intelligent mobility aids, such negative locomotion can not achieve our purpose. Unforced outings of the elderly are different from simple transportations of them, and locomotion styles should not be disincentive for outings. Motivating effects of locomotion styles are essential for our purpose.

On the contrary, although quickly avoiding all oncoming traffic participants would realize speedy locomotion, it would impress rough images on surrounding traffic participants. This kind of locomotion would not achieve the harmonious locomotion because pedestrian areas are not private locomotion environment. Therefore, even emotional and psychological aspects are as important as physical aspects for harmonious locomotion. For considering such aspects of locomotion, various locomotion styles of usual traffic participants seem the key.

For the locomotion on the pedestrian areas, keeping the adequate proximity to surrounding traffic participants is important. Enough proximity allows traffic participants to move smoothly even in the suddenly changeable situations; further, it gives them comfort. On this point, Liu et al. [5] investigated the margin proximity of pedestrians' avoidance, and organized as concept of "personal space". The important point is that personal space is not determined by physical indices such as limit acceleration but by natural behaviors of traffic participants including physical, psychological and emotional factors. In addition, usual traffic participants predict the situations of near future, and adjust the locomotion. If they do not predict the situation at all, the traffic flows of pedestrian areas are sometimes jammed. In such situations, making traffic flows smooth by active acceleration is sometimes better than jamming them by excessively slow and safe locomotion. Since adequate locomotion depends on the contexts, predictions of changes of traffic flow and active controls of velocity are important in some contexts.

As another aspect of pedestrian areas, various kinds of traffic participants coexist. Since their locomotion abilities and social characteristics vary widely according to their mobility type, considering the characteristics of surrounding traffic participants is necessary to realize the harmonious locomotion. For example, it would be strange that the elderly who has decreased locomotive abilities give way to the healthy young who has good locomotion abilities in the situation where either of them needs to avoid. This situation has both a social problem and a problem in locomotive abilities. Implementation of that kind of technologies of unmanned vehicles into welfare intelligent mobility aids has the possibility of making such socially and emotionally strange vehicles. On this point, Kin et al. [6] revealed an implicit order between the types of traffic participants by the survey of attitudinal priorities. Usual traffic participants become acceptable to conform such implicit orders.

These are the examples of interpersonal contexts on pedestrian areas although there are still various interpersonal contexts. This research thought that implementation of the concept of interpersonal contexts into technologies of welfare mobility aids made it possible to realize harmonious autonomous locomotion. The important point is that autonomous locomotion based on interpersonal contexts would contribute to improvements of not only acceptability but also safety and smoothness of locomotion. If the autonomous vehicle conform the interpersonal contexts, they would be accepted as the harmonious traffic participants in spite of machines. This research thought that only such harmonious intelligent mobility aids can realize continuous outing of the elderly.

3 Application Examples of Utilizing Interpersonal Contexts

As the prototype technologies of harmonious autonomous locomotion, this research proposed two kinds of elemental technologies: velocity control based on interaction predication of surrounding pedestrians, and interactive collision avoidance based on surrounding mobility type. This paper explains the concepts and brief results of each technology.

3.1 Hardware of Prototype Intelligent Powered Wheelchairs

Fig. 5 shows the appearance of the prototype of intelligent powered wheelchair used in this research. This vehicle has a laptop for calculation, a monocular camera for capturing video images, and two LIDARs for measuring the distance information. In addition, based on the time-series measurement of the positions of traffic participants, the vehicle estimates their velocity vectors.

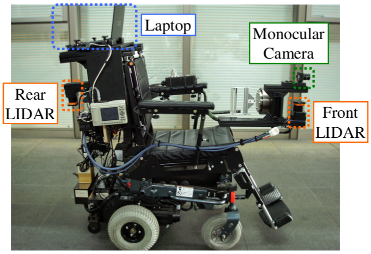

Fig. 5. Developed Prototype Intelligent Powered Wheelchair

3.2 Velocity Control Based on Interaction Prediction of Surrounding Pedestrian

Since locomotion velocities of traffic participants are various, frequent locomotion interactions such as over taking and facial avoidance are conducted on the narrow sidewalks. In such situations, prediction of local traffic is effective for harmonious autonomous locomotion. For example, if the locomotion path of surrounding traffic participants apparently cross the locomotion path of the vehicle in the situation shown in Fig. 6, existing robotic technologies can predict the locomotion of pedestrians and control the vehicle for smooth collision avoidance. On the other hand, in the situation shown in Fig. 7, the observed path of the pedestrian in front does not appear to cross, and he would change his route after a while. If the vehicle kept on moving until the pedestrian in front changed lanes, the situation would become so dangerous that the vehicle might need to make an emergency stop. Emergency stops are a severe problem for welfare mobility aids, though they are not so critical for unmanned robots. Such emergency stop would not be accepted even from surrounding traffic participants, because usual traffic participants can estimate such situations and deal with them easily. The key point is evaluation and prediction from the view point of usual traffic participants.

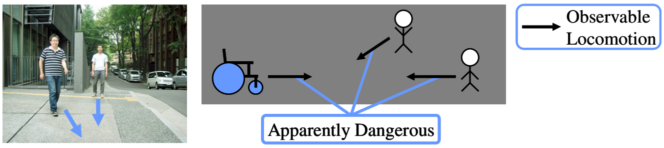

Fig. 6. Apparently Dangerous Situation

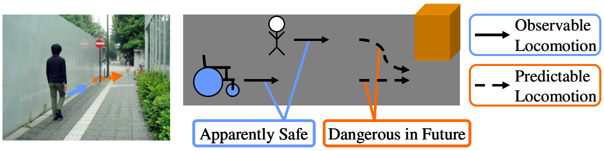

Fig. 7. Apparently Safe but Potentially Dangerous Situation

Thus, for the purpose of predictive autonomous locomotion based on interpersonal contexts, this research developed the algorithm for interaction prediction of surrounding pedestrian based on the relation of their position and velocity, and the algorithm of velocity control. Based on the knowledge about the personal space [5] of pedestrians, the system utilizes prediction of future proximity for its velocity control and makes sufficient margins for safely avoiding other traffic participants. Fig. 8 shows the schematic of the system. At first, the system senses the positions of surrounding traffic participant and obstacles, and the velocities of them. Then, the system estimates the margin time for surrounding traffic participant to change locomotion, and calculates the future proximity at that time. Based on those values, the system controls current velocity for making enough margin space for safely avoiding after a few seconds. The details of the system are described in our previous paper [7]. As a brief result, this system was able to start adjusting the future proximity by active velocity controls about five seconds before the surrounding traffic participant changed the lanes. For dealing with traffic flow smoothly as a usual traffic participant, expanding target situations of prediction is necessary for the next step.

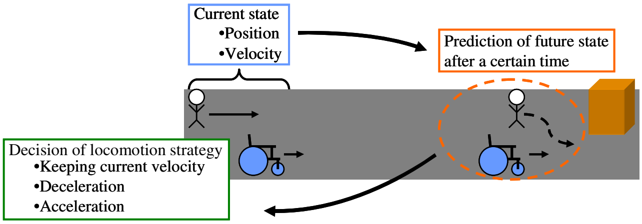

Fig. 8. Schematic of Interactive Control of Velocity Based on Prediction

3.3 Interactive Collision Avoidance Based on Surrounding Mobility Type

On the real pedestrian areas, there are various kinds of traffic participants such as pedestrian, wheelchair users and bicycle riders. They have different locomotion priorities in accordance with their social characteristics and mobility abilities. Thus, consideration of locomotion priorities based on surrounding mobility type is important for harmonious autonomous locomotion. Therefore, this research developed the algorithm of interactive collision avoidance based on surrounding mobility type. Fig. 9 shows the schematic of the interactive strategies. For wheelchair users and slow pedestrians, the vehicle changes lanes to avoid them autonomously when they face each other on the sidewalks. On the other hand, for bicycle riders and fast pedestrians, the vehicle decelerates autonomously with the aim of being passed by. Slow pedestrians are assumed as the elderly, while fast pedestrians are assumed as the healthy young. These interactive strategies would be effective for safe locomotion because active avoidance of traffic participants who has better locomotive abilities can make less risky situations of avoidance. In addition, the strategies would be also effective for acceptable locomotion because they conform the implicit orders of social and attitudinal priorities.

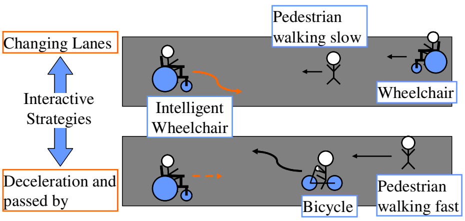

Fig. 9. Schematic of Interactive Collision Avoidance

To realize such interactive collision avoidance, this research developed the classification method of surrounding mobility type. Fig. 10 shows the sequence for mobility type classification. This system classifies the mobility type of an oncoming traffic participant mainly based on the image recognition though the system also uses LIDAR data to get information about position and size of him. Based on the estimated position and size of the oncoming traffic participant, the system extracts the captured image of him. Using the jointHOG detectors [8] of each mobility type, the system calculates the similarity point of the extracted image. Furthermore, in order to reduce the differences of the detecting capability of each detector, the component normalizes each result of moving average with linear discriminant functions. Based on the velocity and the comparison results of the normalized similarity points, the component classifies the mobility type of the detected traffic participant. The accuracy of this classification system in the preliminary experiment was over 80 % at the distance of 9.0m, which was enough far to avoid each other smoothly in an acceptable manner. As the result, the system recognized four kinds of mobility types; young pedestrian, old pedestrian, wheelchair user and bicycle rider, and executed two kinds of interactive collision avoidance; changing lanes for avoidance and deceleration for being avoided. By enhancing the classification system for much more various traffic participants, this system would be improved enough to realize acceptable locomotion. Furthermore, in some other aspects, this research thought that this system achieved human-machine collaborative avoidance, though human did not mean the rider but surrounding traffic participants. In addition, human-machine collaborative technologies like this system would realize interactive safety technologies of locomotion.

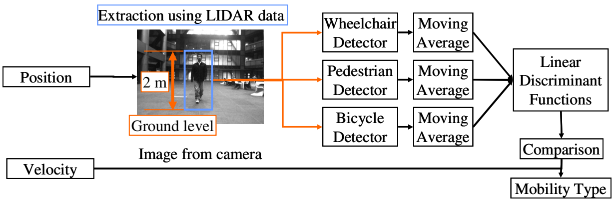

Fig. 10. Sequence for Mobility Type Classification

4 Conclusion

The objective of this study was to develop intelligent welfare mobility aids which had harmonious autonomous locomotion functions for the purpose of continuous outing of the elderly. At first, this research coordinated the concept of harmonious locomotion, and proposed the autonomous locomotion based on the interpersonal context. Then, this paper explained the following technologies briefly.

- Velocity control based on interaction prediction of surrounding pedestrian
- Interactive collision avoidance based on surrounding mobility type

The method of sharing interpersonal contexts focused mainly on the stand-alone sensing systems in this research. However, collaboration system using the telecommunication would be effective. For example, vehicle-to-vehicle and vehicle-to-pedestrian communication system utilizing smartphones would realize the much more interactive autonomous locomotion based on more precise personal information. By developing various applications of utilizing interpersonal contexts, we aim to realize harmonious autonomous welfare mobility aids.

Acknowledgments. This work was supported by Grant-in-Aid for JSPS Fellows 10J08623.

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Comparison of Cognitively Impaired, Healthy Non-Professional and Healthy Professional Driver Behavior on a Small and Low-Fidelity Driving Simulator

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Abstract. It is becoming an important issue to develop methods to evaluate driving capability of cognitively impaired persons. In this paper, we conducted an experiment, by using a small and low-fidelity driving simulator (a Honda Safety-Navi), to collect driving data of several categories of drivers in order to understand what kind of driving activities could be degraded due to the cognitive disabilities. Healthy non-professional drivers, healthy professional bus drivers, patients but not cognitively impaired, drivers cognitively impaired by "higher brain dysfunction" were compared. The results showed that degradation of the skill to stop at an appropriate point required by a stop line is a useful index of the whole driving skill in the experimental conditions.

Keywords: Higher brain dysfunction, driving fitness, disability, safety.

1 Introduction

Today, there are many people with known or suspected cognitive impairment due to traumatic brain injuries, cerebrovascular diseases, etc. Since most of those people have need for driving a car for everyday life, it has been a vital topic to establish techniques to determine the driving fitness of such cognitively impaired persons. Huge amount of researches have been done on this issue (Schultheis, DeLuca & Chute, 2009), and it has been pointed out that a driving test in the real world is the "gold standard" for driving capability assessment. However, such test is time consuming and experts for the assessment are necessary. It would be effective to develop easier methods to assess driving capability at least for screening.

Gianutsos (1994) pointed out that a small and low-fidelity driving simulator is useful to assess driving capability. In fact, many researchers use a small driving simulator for the assessment of driving (see, e.g., Schultheis, Simone, Roseman, Nead,

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S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 490–496, 2013.

Rebimbas, and Mourant, 2006). In order to establish "threshold" of the driving fitness, it is important to develop a database of driving behavior.

We are collecting driving behavior data of cognitively impaired drivers having so-called "higher brain dysfunction" and healthy drivers with using a small and low-fidelity driving simulator. Since there are huge individual differences in driving behavior, it is possible that the distributions of driving behavior are not disjoint between healthy and impaired drivers. In this paper, we compare driving behavior of cognitively impaired, not cognitively impaired but having disabilities, healthy non-professional, and healthy professional drivers.

2 Method

Participants: The following persons participated in this experiment:

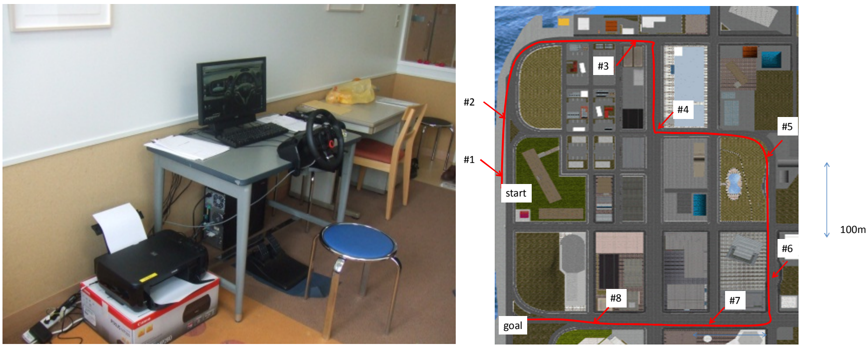
Category 1: 15 healthy non-professional drivers (Gender: 10 male and 5 female, Age: M=65.4, SD=3.5)

Category 2: 5 healthy professional bus drivers (Gender: 5 male, Age: M=49.3, SD=11.9)

Category 3: 8 non-cognitively impaired patients (Gender: 5 male, 3 female, Age: M=71.5, SD=9.1) being afflicted with rheumatism or other diseases

Category 4: 9 patients cognitively impaired by higher brain dysfunctions (Gender: 7 male and 2 female, Age: M=66.0, SD=13.4)

Apparatus and Task: The Honda Safety-Navi (Fig. 1(a)) was used for this experiment. This small and low-fidelity driving simulator is becoming to be used in many hospitals in Japan for evaluating patients' driving capability.



(a) The Honda Safety-Navi (b) Driving course

Fig. 1. Apparatus

Procedure and measures: Before the experiment, each participant received a written explanation of the experiment including the purpose and procedure, and signed the informed consent sheet.

At the experiment, the participants firstly received paper tests in order to investigate the relationship between cognitive ability and driving performance. We conducted the following tests: TMT-A (Trail Making Test Part A), TMT-B, Digit Symbol-Coding (WAIS-III), and Zoo map test of the BADS.

Second, driving tests were done. The driving tests consisted of a simple reaction test, a selective reaction test, and the driving test in a town. In the simple or selective test, the drivers, who were driving a straight road, were asked to apply brake when a specified visual signal appeared in the screen. The reaction time from the appearance of the visual signal to applying brake was recorded for each trial.

In the driving test in a town, we counted how many inappropriate actions were done for each driver. The inappropriate actions in this paper consist of: too hard deceleration, exceeding the speed limit, inappropriate stopping where the stopped position is too far from the required stopping line, and lack or too late activation of turning signal.

In the town driving scenario in the Honda Safety-Navi, the following eight events (#1 - #8) (Fig. 1(b)) occur:

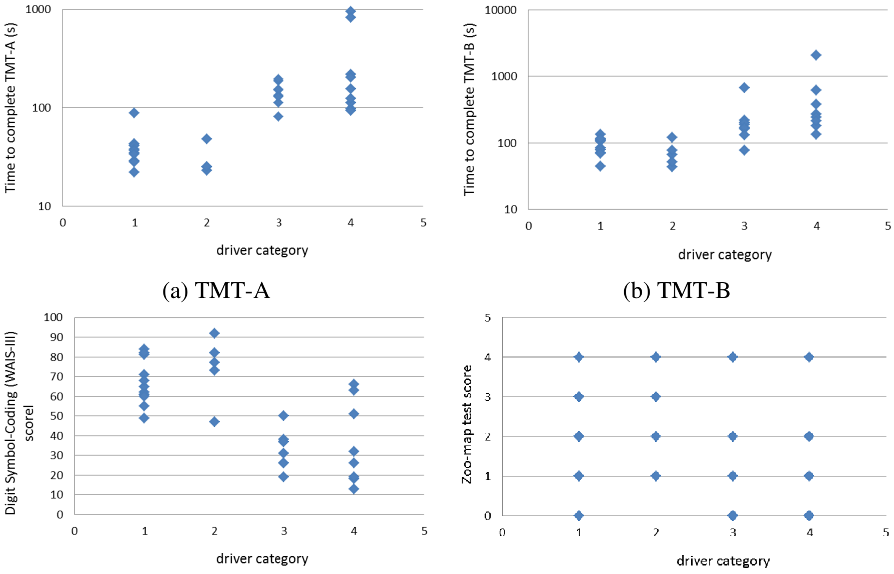
#1: A vehicle comes from behind and passes the host vehicle when the host vehicle tries to start driving.
#2: A vehicle in the passing comes from behind lane when the host vehicle is going to enter the passing lane. If the host vehicle driver does not recognize the passing vehicle, a collision could occur.
#3: A vehicle enters a crossing from right just before the host vehicle enters the crossing.
#4: A motorbike enters the left blind spot when the host vehicle is stopping at the stop line (the traffic right is in red).
#5: A large truck is stopping on a one-lane road. The door at the driving seat of the truck opens just before the host vehicle passes the truck.
#6: A small personal mobility vehicle appears suddenly from a house which is adjacent to the road and enters the road.
#7: A taxi in the passing lane changes lanes and stops suddenly when the host vehicle is driving in the cruising lane. It is because a person on a sidewalk is calling a taxi. The taxi crosses the lanes just before the host vehicle.
#8: A vehicle in the passing comes from behind when the host vehicle is going to enter the passing lane.

In each case, a collision could occur if the host vehicle driver fails to recognize the other vehicle or fails to predict or understand the behavior of the other vehicle. However, the collision can be avoidable because several visual clues are available for each case. We observed the driver behavior for each event and investigated whether he or she could avoid a collision easily or not. Thus the number of crashes was counted for each driver. Note that crashes could occur in other situations than the above 8 events.

We investigate the relationships between the number of inappropriate actions and the scores of paper tests.

3 Results and Discussion

Fig. 2 shows the results of the paper tests. It should be noted that there is no clear threshold which distinguish healthy drivers (categories 1 and 2) and patients (categories 3 and 4) for each test, even though the healthy drivers tend to have good scores except for the Zoo map test. It is apparent from this result that these paper tests only are not enough to evaluate the subject driving capability.

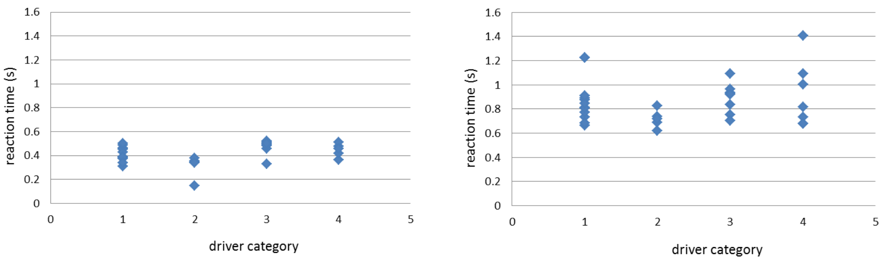


(a) TMT-A (b) TMT-B

(c) Digit symbol coding (d) Zoo-map test

Fig. 2. Reaction time test

Interestingly, there was no significant difference among the four categories of drivers in terms of the reaction times (Fig. 3). That is, the reaction time of the patients is not so late! Another thing to mention here is that the category 2 (healthy professional bus drivers) could react quickly. Again, measuring reaction time is not enough to evaluate the subject driving capability.



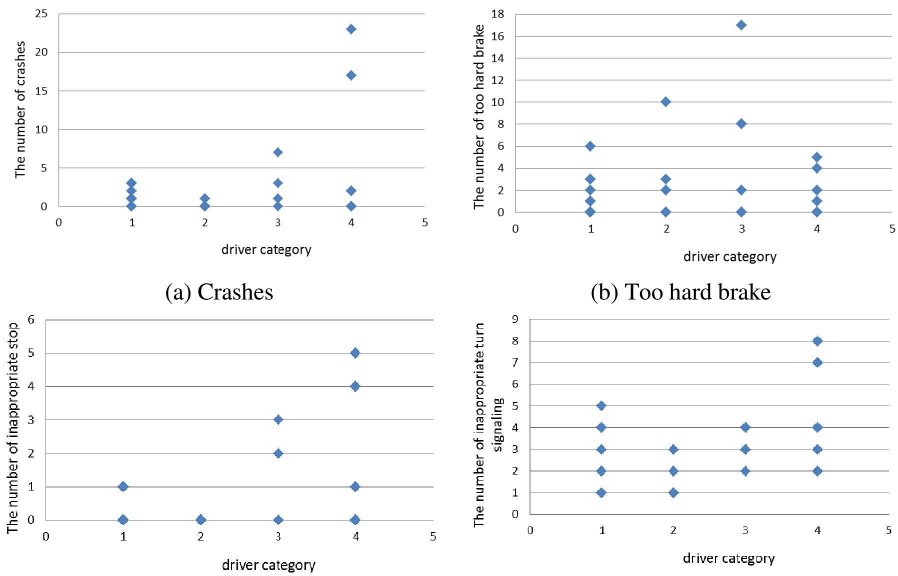
(a) Simple reaction time (b) Selective reaction time

Fig. 3. Reaction time tests

Fig. 4 illustrates the numbers of crashes and inappropriate actions occurred during driving in the town course. Some patients experienced many crashes, but the other patients caused only small number of crashes which are almost equivalent to the ones of the healthy drivers. It should be noted that the professional bus drivers experienced very small number of crashes (Fig. 4(a)).

It is interesting that too hard brake tended to be few for the patients of higher brain dysfunctions (Fig. 4(b)). This would be because those patients driven slowly, and because their power to apply the brake was weak. On the other hand, the professional drivers did many number of too had brakes, because the pedal was too light compared to the real brake pedals. Similarly, there was no difference among the driver categories for the inappropriate turn signaling (Fig. 4(d)). It should be noted that these two types of inappropriate actions (i.e., too hard brake and inappropriate turn signaling) could be done even by healthy, especially professional drivers.

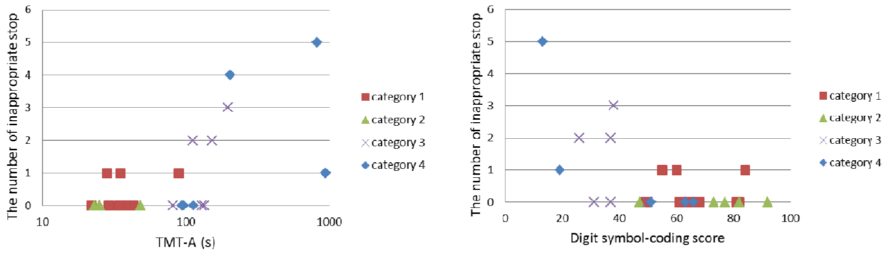
On the other hand, the patients tended to be troubled but the others did not with stopping at an appropriate point (Fig. 4(c)). The inappropriate stops are related to cognitive ability and driving capability. Fig. 5 shows the relationships between paper tests and the number of inappropriate stops. The correlation coefficient between the TMT-A score and the number of inappropriate stops was 0.58 ($p<0.05$), and that between the digit symbol-coding score and the number of inappropriate stops was -0.59 ($p<0.05$). Fig. 6 shows the relationship between the number of crashes and the number of inappropriate stops. The correlation coefficient between these two was 0.84 ($p<0.05$). Thus, it would be effective focus our attention to drivers' stopping actions to a stop line in this driving simulator.



(a) Crashes (b) Too hard brake

(c) inappropriate stop (d) inappropriate turn signaling

Fig. 4. Inappropriate actions



(a) Crashes (b) Too hard brake

Fig. 5. Relationship between paper tests and the inappropriate stop

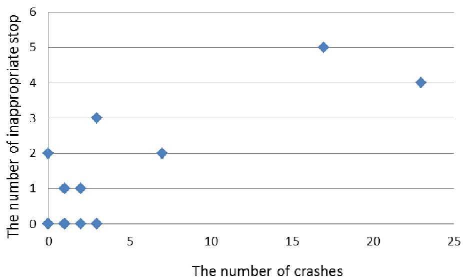


Fig. 6. Relationship between the inappropriate stops and crashes

4 Concluding Remarks

In this paper, we have compared driving behavior among healthy non-professional drivers, healthy professional bus drivers, patients but not having higher brain dysfunctions, and drivers cognitively impaired by higher brain dysfunctions. As literature suggests, no single test was not good enough to evaluate driving capability. In fact, even the impaired drivers could show better performance to paper tests and reaction tests. In this experiment, the number of inappropriate stops was a good index to evaluate the driving fitness. Since there were significant correlations between TMT-A, Digit symbol-coding, the number of inappropriate stops, and the number of crashes, it would be useful to use these measures to evaluate driver fitness.

From a clinical point of view, establishing a simple and/or easy method to evaluate driving capability for screening is important to reduce the risk of patients' driving. On the other hand, evaluating driving fitness of a patient is not enough. From an engineering point of view, it is important to clarify ways to assist safe driving of such cognitively impaired drivers. It is apparent that it is almost impossible to remove all risks of the cognitively impaired drivers, but the authors believe there do exist some kinds of impairedness could be overcome by providing an appropriate engineering support. Further studies are necessary to find what types of impaired drivers could drive in the real world by receiving some appropriate cognitive assistance from a driver assistance system.

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Influence of the Safety Margin on Behavior that Violates Rules

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Abstract. This research was undertaken to explore how the safety margin influenced the occurrence of the risk-taking behavior that violated the rules through an experiment where the participants were required to carry out a go-around task in which a simulated railroad crossing was included. Three levels of the waiting time for the train coming with the flashing light signal at the crossing were settled as the safety margins. The results of the experiment suggested that the large safety margin might cause to make the subjective probability of the failure of the violation and the subjective probability of receiving punishment for the violation decreased and the tendency toward the violation. The results of the simulation suggested that the violation occurrence could be explained by the expected utility theory.

Keywords: Safety margin, Violation, Subjective probability, Expected utility theory.

1 Introduction

Generally a system should keep enough margin of the safety. However at railroad crossings, warning times in excess of a certain lengthy period cause many drivers to engage in risky crossing behavior during the warning period (Richard and Heathington(1990), Witte and Donohue(2000), Caird et. al.(2002)). At intersections with a signal, pedestrians get impatient and violate the traffic signal as signal waiting time increases (Geetam et. al.(2007)).

These phenomena indicate that the large margin of the safety in a system might make the system users underestimate the risk of the violations such as driving around lowered gates and/or ignore the flashing lights at railroad crossings and jaywalking at signalized intersections. That is, the large safety margin might influence the occurrence of the risk-taking behavior of the system users that violates the rules.

This research was undertaken to explore how the safety margin influenced the occurrence of the risk-taking behavior that violated the rules through an experiment where the participants were required to carry out a task in which a simulated railroad crossing was included.

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S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 497–506, 2013.

2 Methods

2.1 Participants

Twenty one male and nine female undergraduate students of Tokai University voluntarily participated in the experiment. Their average age ± standard deviation was 21.10 ± 1.18 years. They were divided into three groups (Group A, B, and C). Each group was consisted of seven male and three female students. The average ages were 21.10±1.10 (Group A), 21.40±1.43 (Group B), and 20.80±1.03 years (Group C) respectively.

2.2 Experimental Task

The participants were required to carry out the go-around task. In the go-around task, the participants were required to make the target complete a loop course in a counterclockwise direction five times within 550 seconds. The participants could control the direction and the movement of the target by pushing a right, a left, an up, or a down cursor key of a 108-key Japanese keyboard. The loop course had a simulated railroad crossing with the flashing light signal and the participants were prohibited to make the target cross the track when the signal was activated. They were also prohibited to make the target return the way they came. In this experiment these were defined as the violations; that the participants ignored the prohibitions and engaged in risk-taking behavior.

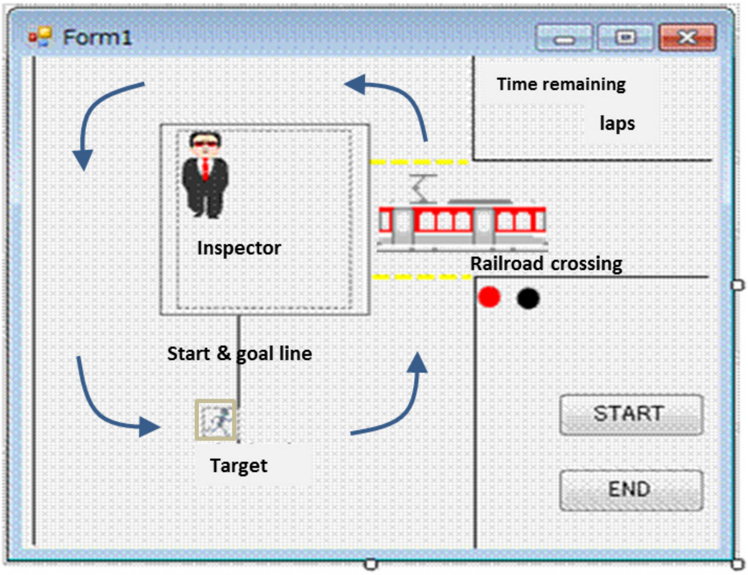

Fig. 1. Experimental task

2.3 Conditions

As the literature suggested that violations at the rule-based level were the outcome of cost-benefit trade-offs (Maurino et. al. (1995), Gurjeet(2004)), some payment rules and temporal constraints were settled in order to explore how the safety margin influenced the violation occurrence through the experiment.

1,000 Japanese yen was given to all the participants as the basic fee before the experiment. The participants were paid the bonus, 10 yen per second, equivalent to the remaining time in case that the target could reach the goal and the remaining time was more than 150 seconds. In contrast the participants forfeited the basic fee, 1,000 yen, and earned nothing in case that the target could not reach the goal within 550 seconds. If the train crashed into the target at the crossing, the task was over immediately. It meant that the participants also forfeited the basic fee, 1,000 yen, and earned nothing in case that the train crashed into the target at the crossing.

The participants could make the target complete the loop course in about 30 seconds if any interference did not exist in the course and it took 10 seconds for the target to cross the track. Three levels of the waiting time for the train coming with the flashing light signal were settled as the safety margins, 30 seconds for Group A, 20 seconds for Group B, and 10 seconds for Group C. After the task was started or the previous flashing light signal was stopped, the signal began to be activated in about 30 seconds. The warning time was the same under all the groups and 77 seconds by controlling the velocity of the train in order to filter out the influence of the delays between groups as the literature suggested that the long delays by some interference tended to cause the risky violation (Sanders (1976), Geetam et. Al. (2007)). If the inspector who appeared randomly at the crossing detected a violation by the participants, their remaining time was decreased by 30 seconds with each detection as the punishment of the violation.

2.4 Procedure

At first the experimental task and conditions which included the violation, the payment rules and temporal constraints were explained to the participants and the basic fee, 1,000 yen, was paid to them. After the explanation and the payment, the participants carried out the pretrial task whose safety margin was 20 seconds in order to understand the task completely. Next, the participants just gazed at the railroad crossing for 300 seconds during the task whose safety margin depended on the attached group in order to experience their own margin. The participants could experience their own margin three times. After their own margin experience, the participants estimated four kinds of the subjective probabilities. Finally the participants carried out the task and the payments for the participants were settled according to the task performance.

2.5 Apparatus

The experiment was conducted on an SONY PC (VGN-FJ11B) with the 108-key Japanese keyboard (ELECOM TK-U08FYSV). The experimental task was presented by the program which was written in Visual Basic 2008 and run under Windows XP Home edition. Every task by every subject was recorded by the digital video camera

(Panasonic-SDR-H80) and the camera which could be gripped on the edge of the PC display and record the PC display (System creates Sha-miel). The visual distance between participant's eyes and the display was about 0.6m.

2.6 Measures

The number of the violation at the railroad crossing was measured as the performance. The remaining time in case that the target reached the goal was also measured. Four kinds of the subjective probabilities were measured through the subjective estimation to the own margin experience as follows;

P1: the probability that the train crashed into the target when the participant made a violation at the railroad crossing.
P2: the probability that the inspector detected the violation when the participant made a violation at the railroad crossing.
P3: the probability that the target could reach the goal within 550 seconds in case that the participant made a violation at the railroad crossing.
P4: the probability that the target could reach the goal within 550 seconds in case that the participant did not make any violation at the railroad crossing.

3 Results

Tukey's WSD was applied to take account of multiple comparisons of the ratio of the violation occurrence between three levels of the safety margin. The ratio in case of the large safety margin (30 sec) was significantly higher than in case of the small margin (10 sec) ($0.6>WSD=0.51$, $p<0.05$) as shown in Fig,2. A one-way ANOVA and Tukey's HSD were applied to take account of multiple comparisons of the number of violations between three levels of the safety margin. The result of the ANOVA revealed that there was the significant difference between levels of margin ($F(2,27)=6.55$, $p<0.01$). The results of Tukey's HSD revealed that the number of violations in the large margin was significantly larger than in the small margin ($t=3.60 > q(3,27, 0.01)/\sqrt{2}$) as shown in Fig.2. These results revealed that the large margin was likely to cause the tendency toward the violation.

A one-way ANOVA and Tukey's HSD were applied to take account of multiple comparisons of the remaining time between three levels of the safety margin. The result of the ANOVA revealed that there was the significant difference between levels of margin ($F(2,27)=6.88$, $p<0.01$). The results of Tukey's HSD revealed that the remaining time in large margin was longer than in the small margin ($t= 3.68 > q(3,27, 0.01)/\sqrt{2}$) and also tended to be longer than in the medium margin (20 sec)($t=2.21 > q(3,27,0.10)/\sqrt{2}$) as shown in Fig.3. These results revealed in the large margin the participants could get the longer remaining time than in other margins by making the violations.

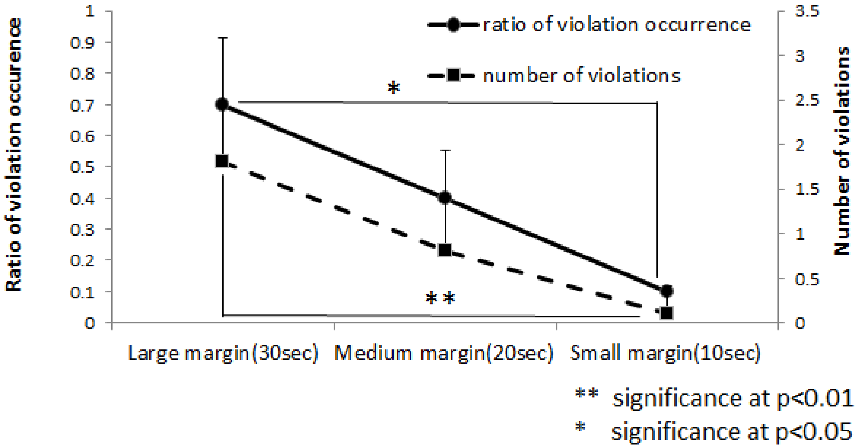

Fig. 2. Violation occurrence

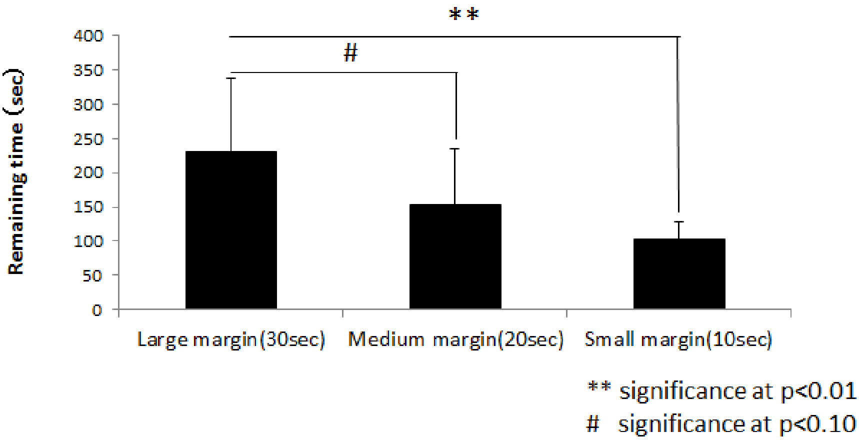

Fig. 3. Remaining time

A one-way ANOVA and Tukey's HSD were applied to take account of multiple comparisons of P1 between three levels of the safety margin. The result of the ANOVA revealed that there was the significant difference between levels of margin ($F(2,27)=16.29$, $p<0.01$). The results of Tukey's HSD revealed that P1 in the large margin ($t= 5.31 > q(3,27, 0.01)/\sqrt{2}$) and in the medium margin ($t= 4.46 > q(3,27, 0.01)/\sqrt{2}$) were significantly lower than in the small margin as shown in Fig.4. These results revealed that in the large and medium margin the participants estimated the probability of the failure of the violation lower than in the small margin.

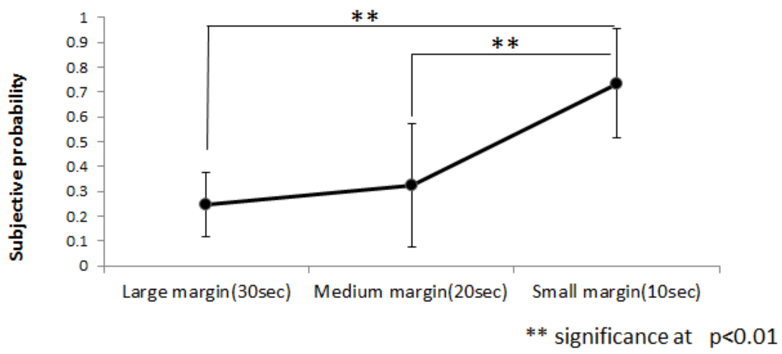

Fig. 4. Subjective probability (P1)

A one-way ANOVA and Tukey's HSD were applied to take account of multiple comparisons of P2 between three levels of the safety margin. The result of the ANOVA revealed that there was the significant difference between levels of margin ($F(2,27)=6.66$, $p<0.01$). The results of Tukey's HSD revealed that P2 in the medium margin was significantly higher than in the large margin ($t= 3.65 > q(3,27, 0.01)/\sqrt{2}$) as shown Fig.5. These results revealed that in the medium margin the participants estimated the probability of the detection of the violation by the inspector higher than in the large margin.

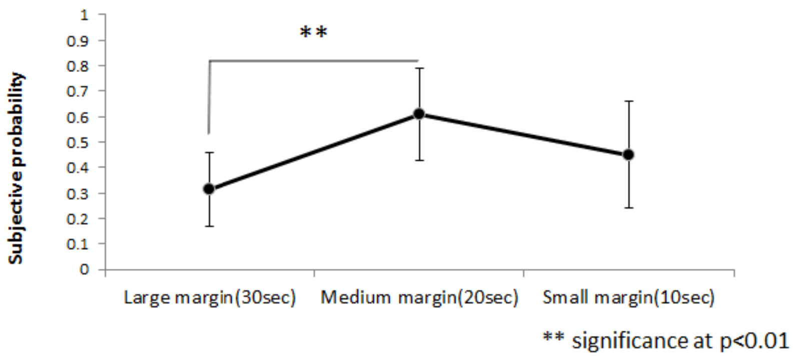

Fig. 5. Subjective probability (P2)

A two-way mixed ANOVA with levels of margin as the between-subjects variable and subjective probabilities (P3 and P4) as the within-subject variable was carried out. The result of the ANOVA revealed that there were the significant differences between levels of margin ($F(2,27)=6.78$, $p<0.01$) and between subjective probabilities ($F(1,27)=122.73$, $p<0.01$, and that there was also significant interaction between levels of margin and subjective probabilities ($F(2, 27)=9.55$, $p<0.01$). The results of the simple main effect test revealed that there was no significant difference between levels of margin in P4 ($F(2,27)=0.67$, $p>0.10$), that there was the significant difference between levels of margin in P3 (F(2,27)=8.85, p<0.01), and that P3 was significantly higher than P4 regardless of levels of margin (F(1,27=11.73) (large margin), 38.07 (Medium margin), 92.05 (Small margin), p<0.01). Tukey's HSD was applied to take account of multiple comparisons of P3 between three levels of the safety margin and the results revealed that P3 in the large margin (t= 4.16 > q(3,27, 0.01)/√2) and in the medium margin (t= 2.63 > q(3,27, 0.05)/√2) were significantly higher than in the small margin. These results revealed that the participants estimated the probability of the success in the target's reaching the goal within 550 seconds in case that the participants made a violation lower than in case that they did not make any violation regardless of the levels of the safety margin, and that in the large and medium margin they estimated the probability higher than in the small margin. These meant that the participants might estimate "the subjective probability of the success in the target's reaching the goal within 550 seconds in case that they made a violation at the railroad crossing", P3, as the joint probability of the success in the target's reaching the goal within 550 seconds as well as the success of the violation.

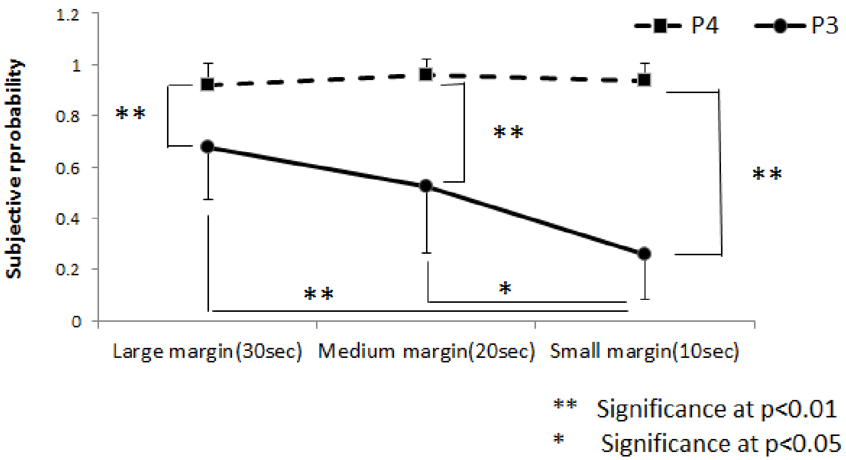

Fig. 6. Subjective probabilities (P3, P4)

4 Discussions

From the results of the experiment it was revealed that the large safety margin was likely to cause the tendency toward the violation even though the delay time by all levels of the safety margin was the same. The results of the experiment also revealed that in the large and medium safety margins the participants estimated the possibility that the train crashed into the target with a violation lower than in the small safety margin and that in the large safety margin the participants estimated the subjective probability of the detection by the inspector relatively lower than in the medium safety margin. It meant that the large safety margin was likely to cause the low subjective probability of the failure of the violation and the low subjective probability of receiving punishment for the violation, and that these subjective probabilities influenced the tendency toward the violation in the large safety margin.

It suggested that the safety margin influenced the subjective probability of the failure of the violation, the subjective probability of receiving punishment for the violation, and the occurrence of the violation, and that the large safety margin might cause to make these subjective probabilities decreased and the tendency toward the violation.

Additionally, the results of the experiment also revealed that the participants estimated the possibility that the target could reach the goal within 550 seconds in case that they made a violation was lower than in case that they did not make any violation regardless of the levels of the safety margin, that is, the participants estimated that the possibility to earn nothing in case that they made a violation was higher than in case that they did not make any violation regardless of the levels of the safety margin as the failure to reach the goal meant the forfeit of the basic fee. It meant that even though the participants estimated that the violation increased the possibility to earn nothing regardless of the levels of the safety margin, the large safety margin was likely to cause the tendency toward the violation. This suggested that the tendency toward the violation in the large safety margin could not be explained only by the subjective probabilities.

The occurrence of driver's risk-taking behavior was frequently explained by using the expected utility theory (Blomquist (1986), Matsuo et. al. (2010)). As Murano et. al. (1995) described that violations at the rule-based level tended to be deliberate acts carried out in the belief that they would not result in bad consequences and that such violations were the outcome of cost-benefit tradeoffs-with the benefits exceeding the costs, the violation occurrence could be also explained by the expected utility theory. This research tried to explain the results of this experiment by the expected utility theory.

$$U = I - P_1(v)L_1 - \big(1 - P_1(v)\big)P_2(v)P_3(v)L_2 - \big(1 - P_1(v)\big)\big(1 - P_1(v)\big)\big(1 - P_3(v)\big)L_3 - \big(1 - P_1(v)\big)\big(1 - P_1(v)\big)P_3(v)L_4(v) - D(v) \qquad (1)$$

U: Expected utility

I: Maximized income

v: Violation status

v=1 violation occurrence, v=0 no violation occurrence

$P_1(V)$: the probability that the train crashed into the target when the participant made a violation at the railroad crossing

$P_1(1)$=P1, $P_1(0)$=0

$P_2(V)$: the probability that the inspector detected the violation when the participant made a violation at the railroad crossing.

$P_2(1)$=P2, $P_2(0)$=0

$P_3(v)$: the probability that the target could reach the goal within 550 seconds at the railroad crossing.

$P_3(1)$=P3/(1-P1) ; as mentioned above, P3 might be estimated as the joint probability of the success in the target's reaching the goal within 550 seconds as well as the success of the violation.

$P_3(0)$=P4

L1: loss by train crash; 2,150 yen, the averaged income of the participants who made the violation in the experiment.

L2: loss by punishment for the violation, 300 yen, 30 seconds, penalty, times 10 yen

L3: Forfeit of basic fee by the time's up, 1,000 yen

$L_4(v)$: loss by waiting the train at the crossing,

$L_4(1)=0$, $L_4(0)$=770 yen ; 77 seconds times 10 yen

D(v): Disutility Cost D(1)=D(0)

Equation (1) shows that expected utility equals the maximum income minus the subjective probability of the train crush times the loss if the crash occurs, minus the subjective probability of the inspector's detection of the violation times the loss if the inspector detects a violation, minus the subjective probability of the time's up of the game times the forfeit of the basic fee if time's up, minus the subjective probability of reaching the goal within the time constraints times the loss by waiting the train at the crossing, minus the disutility cost for the behavior. The participants decide whether they make the violation or not according to the larger expected utility of equation (1) in cases of both violation occurrence and no violation occurrence.

In order to estimate the validity of equation (1) the Kappa coefficient between the results of the experiment and the simulated results by the equation (1) was calculated. The Kappa coefficient was 0.58 ($p<0.01$) and revealed that the simulated results were corresponding to the results of the experiment. It meant that the violation occurrence could be explained by the expected utility theory as well as driver's risk-taking behavior.

In this simulation, L1, loss by train crash, was set as the averaged income of the participants who made the violation in the experiment and were assigned 2,150 yen because L1 could not be defined by any other objective information in this research. However there is not any confirmation of this assignment. At the actual train crossings, L1 is related to the value of the violator's life and it is impossible to measure L1 objectively. Additionally, there is neither confirmation that the participants applied the objective values of other losses to the decision making whether they made a violation or not. Further research is needed in order to reconfirm that the violation occurrence could be explained by the expected utility theory when the subjective values of the losses as well as the subjective probabilities, are applied instead of the objective ones.

5 Conclusions

This research was undertaken to explore how the safety margin influenced the occurrence of the risk-taking behavior that violated the rules through an experiment.

In the experiment the participants were required to carry out a go-around task in which a simulated railroad crossing was included and the participants were required to make the target complete a loop course in a counterclockwise direction five times within 550 seconds. The loop course had a simulated railroad crossing with the flashing light signal and the participants were prohibited to make the target cross the track when the signal was activated. Three levels of the waiting time for the train coming with the flashing light signal at the crossing were settled as the safety margins, 10 seconds, 20 seconds, and 30 seconds.

The results of the experiment suggested that the safety margin influenced the subjective probability of the failure of the violation, the subjective probability of receiving punishment for the violation, and the violation occurrence, and that the large safety margin might cause to make these subjective probabilities decreased and the tendency toward the violation. The results of the simulation suggested that the violation occurrence could be explained by the expected utility theory.

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Determination of Alarm Setpoint for Alarm System Rationalization Using Performance Evaluation

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Abstract. Alarm system is one of the most important element of the plant-operator interfaces in the industrial plants. Alarm lifecycle management is very important to maintain the safety, quality, environmental and economic efficiency of the plant. In our previous study, we proposed the method to select adequate alarm variables and evaluation method in diagnostic and timely manner. In this study, we proposed a method to determine the setpoints for alarm system using three indices and the results of dynamic process simulation on the rationalization stage of the lifecycle of alarm management. And we also presented feasibility of our method by demonstration of a case study.

Keywords: Plant Alarm System, Dynamic Process Simulation, Timeliness rate.

1 Introduction

Information from sensors in the chemical plants is displayed on the console through the DCS (Distributed Control System). Plant operators can observe the plant situation by sweeping the console, and they can control the plant by sending control signals to the control elements via DCS. If any malfunction occurs in the plant, it is necessary to detect it as early as possible and to take adequate actions to bring the plant situation back to normal in order to avoid any industrial accident, quality and environmental performance degradation. Plant alarm system is one of the most important operator-plant interfaces to attract operators' attention by blinking and/or beeping in order to recognize the plant situation and to take counter measures in such a context. However consecutive and simultaneous generations of a large number of plant alarms cause congestion of information on the console or impediment of operators' recognition of the plant situation, if the each and every alarm source signals are set as alarm variables. New laws, regulations and guidelines for the plant safety have been established because of the repetition of the industrial accidents due to the alarm floods or the inadequate alarm systems.

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 507–514, 2013.

EEMUA[1] set a benchmark for the number of alarm generations in ten minutes following a plant upset from an ergonomics standpoint. And EEMUA also proposed the eight characteristics—which are *Relevant*, *Unique*, *Timely*, *Prioritized*, *Understandable*, *Diagnostic*, *Advisory* and *Focusing*— of a good alarm. ISA proposed the standards for the lifecycle of alarm management in SP18.2 [2]. The third stage named "*Rationalization*" was defined which consists of several steps—*Alarm validity*, *Consequences*, *Operator response*, *Response time*, *Alarm priority*, *Alarm class*, *Setpoints*, *Advanced alarm handling*— in the standards for the lifecycle of alarm management of ISA SP18.2. Thorough streamlining of alarms following the standardized design and management approaches was advocated by ISA. However the concrete methods of design, evaluation and enhancement of the alarm system have not mentioned in these guidelines and standards.

Takeda *et al.* [3] proposed the alarm variable selection method among an enormous number of alarm source signals by using two-layer cause-effect model to design the "diagnostic" plant alarm system. In their method, it is possible to systematically acquire the combinations of alarm variables, which can qualitatively and theoretically distinguish among all the assumed plant malfunctions. It is difficult to determine which combinations of alarm variables should be used, because of the large number of combinations of alarm variables by their method. In our previous studies [4,5], we proposed three indices—effective rate, recall rate and timeliness rate— to evaluate performance of plant alarm system. Therefore, we could not provide the method to enhance the performance of the plant alarm system, even though we could propose how to evaluate it. In this study, we investigate a method to determine the setpoints for alarm system using the three indices and the results of dynamic process simulation on the rationalization stage.

2 Evaluation Method for Plant Alarm System

2.1 Diagnostic Alarm Variables Derived by Two-Layer Cause-Effect Model

In our previous study[3], we proposed an alarm variable selection method based on a two-layer cause-effect model. The model represents the cause and effect relationships between the deviations of state variables, such as process variables and manipulated variables, from normal fluctuation ranges. It is represented by a directed graph, where two types of nodes are defined.

- i+: Upward deviation of state variable i from normal fluctuation range
- i-: Downward deviation of state variable i from normal fluctuation range

Figure 1 shows an example of the two-layer cause-effect model. A single direction arrow links the deviation of a state variable and its affected state variable. The letters F and L indicate flow rate and tank liquid level, respectively. In our previous study, the sets of the state variables with the directions of their deviation from the normal fluctuation ranges are derived. If the alarm setpoints are adequately configured, the derived sets are theoretically guaranteed to be able to qualitatively distinguish all the assumed malfunctions in a plant. In this study, the derived sets are referred to as the sets of the diagnostic alarm variables.

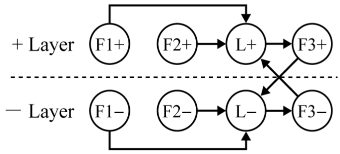

Fig. 1. Example of two-layer cause-effect model

2.2 Performance Evaluation Indices of Plant Alarm System

Three indices, "*effective rate*", "*recall rate*" and "t*imeliness rate*" have been introduced to evaluate the diagnostic characteristic and timeliness characteristics of a plant alarm system in our previous study [4,5]. Alarms are classified by diagnostic characteristic and activation status. As shown in Table 1, w is the number of actually activated distinguishable alarms, x is the number of non-activated distinguishable alarms, and y is the number of the activated non-distinguishable alarms. The effective rate (*i.e.* the percentage of actually activated distinguishable alarms to all the activated alarms) is calculated using Eq. (1). The recall rate (*i.e.* the percentage of actually activated distinguishable alarms to all the designated distinguishable alarms) is calculated using Eq. (2). High effective and recall rates indicate that the alarm system possesses strong enough characteristic to identify the root causes of assumed malfunctions of the plant. And timeliness rate is calculated using Eq. (3), for evaluating the timeliness characteristic of a plant alarm system. In Eq. (3), t_e is the elapsed time from the beginning of the malfunction till when all the alarms are activated to distinguish the malfunction and t_a is the longest available time of t_e. t_a is determined in accordance with the plant dynamics considering the time it takes for operators to respond and correct the problem. A low timeliness rate indicates that the plant alarm system generates diagnostic alarms too late for operators to respond and correct the problem in a timely manner.

$$\text{Effective rate [\%]} = w\,/\,(w + y) * 100 \tag{1}$$

$$\text{Recall rate [\%]} = w\,/\,(w + x) * 100 \tag{2}$$

$$\text{Timeliness rate [\%]} = \begin{cases} 100 & \text{if } 0 \le t_e \le t_a \\ 100\left(1 - \dfrac{t_e - t_a}{0.5t_a}\right) & \text{if } t_a < t_e \le 1.5t_a \\ 0 & \text{if } 1.5t_a < t_e \end{cases} \tag{3}$$

Table 1. Criteria of diagnostic alarm system

	No. of activated alarm signals	No. of non-activated alarm signals
Number of distinguishable alarm signals	w	x
Number of non-distinguishable alarm signals	y	–

3 Case Study

3.1 Example Plant and Plant Alarm System

A case study with the two-tank system illustrated in Fig. 2 as an example plant was carried out to demonstrate the proposed method. In Fig. 2, the product is fed to Tank 1 and transferred to Tank 2. A certain amount of the product is recycled to Tank 1 from Tank 2. The letters *P*, *F*, *L*, and *V* in Fig. 2 indicate pressure, flow rate and liquid level sensors, and valve positions, respectively. In this example plant, five types of malfunctions are assumed to be distinguishable from the operation of the plant alarm system. And t_a for each malfunction is indicated below:

Mal-1: High feed pressure (t_a= 129 min.)
Mal-2: Low feed pressure (t_a = 129 min.)
Mal-3: Blockage in recycle pipe (t_a = 42 min.)
Mal-4: Wrong valve operation of V4 open (t_a = 129 min.)
Mal-5: Wrong valve operation of V4 close (t_a = 129 min.)

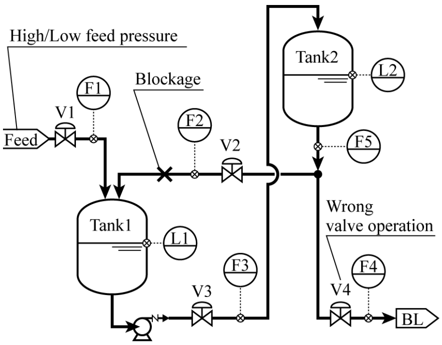

Fig. 2. Example plant of two-tank system

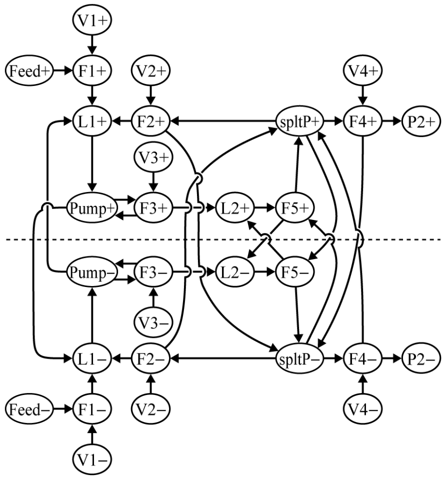

Fig. 3. Two-layer cause-effect model

Figure 3 shows the two-layer cause-effect model of the example plant. To distinguish the above 5 malfunctions, 2 types of alarm setpoints, high limit (PH) and low limit (PL), for 3 measured process variables were set as shown in Table 2. If the value of a state variable exceeds the corresponding alarm setpoint, the corresponding alarm is activated.

3.2 Results of Diagnostic Alarm Selection

All the sets of diagnostic alarms for the example plant, which can be theoretically used to distinguish all assumed malfunctions, were derived from the two-layer cause-effect model by using our previously reported diagnostic alarm selection method (Takeda *et al.*, 2010). The minimum number of sensors used as distinguishable alarm signal was three. To distinguish the five assumed malfunctions, two types of alarm signals—high limit (PH) and low limit (PL)—were adopted. Table 2 shows an example set of the minimum number of distinguishable alarm signals { F1, L1, V4 }, and the normal values, the initial setpoint values of each variables and the alarm activation patterns for each assumed malfunction.

Table 2. Alarm system and their PH/PL limits and activation patterns.

Measured variables		F1 [kg/hr]		L1 [m]		V4 [%]	
	Normal values	5603		2.20		77.7	
	Signals	PH	PL	PH	PL	PH	PL
	Initial setpoints	5883	5323	2.31	2.09	81.6	73.8
Alarm activation patterns	Mal-1	○		○			
	Mal-2		○		○		
	Mal-3				○		
	Mal-4				○	○	
	Mal-5			○			○

3.3 Evaluation Results for Each Assumed Malfunction

Table 3 shows the activated alarms, their activation times from the beginning of the malfunction—which were obtained using a dynamic plant simulator (Visual Modeler, Omega Simulation Co., Ltd.)—, t_e, and the evaluation values.

In Mal-1, F1.PH was not activated although F1.PH is a member of the alarm signal set to distinguish Mal-1. Therefore it could not be distinguished between Mal-1 and Mal-5 at the moment of only L1.PH activation. For this reason, recall rate is 50 % and timeliness rate is indeterminable.

Table 3. Alarm activation times for each assumed malfunctions in simulation.

	t_a [min.]	Alarm signals	*Activation times [min.]	t_e [min.]	Evaluations		
					Effective rate	Recall rate	Timeliness rate
Mal-1	129	F1.PH	Non-activated	†N.D.	100%	50 %	†N.D.
		L1.PH	106				
Mal-2	129	F1.PL	0	0	100 %	100 %	100 %
		L1.PL	100				
Mal-3	42	L1.PL	68	68	100 %	100 %	0 %
Mal-4	129	V4.PH	0	0	100 %	100 %	100 %
		L1.PL	110				
Mal-5	129	V4.PL	0	0	100 %	100 %	100 %
		L1.PH	129				

*Activation time from the beginning of the malfunction.

†N.D. means "Non-Distinguished."

In other malfunctions, because all and the only distinguishable alarm signals are activated, both effective rates and recall rates are 100 %. In Mal-2, the activation times of F1.PL and L1.PL are 0 minute and 100 minutes respectively. If F1.PL is activated, it could be distinguished Mal-2 without L1.PL activation, because F1.PL is not a member of the other alarm signal sets to distinguish the assumed malfunctions except Mal-2. Therefore t_e for Mal-2 is determined as the activation time of F1.PL. In the same manner, t_e for Mal-4 and t_e for Mal-5 are also determined as the activation time of V4.PH and V4.PL respectively. As a result timeliness rates for Mal-2, Mal-4 and Mal-5 are 100 %. However, timeliness rate is 0 % for Mal-3, because the activation time of L1.PL was 68 minutes though t_a for Mal-3 is 42 minutes.

3.4 Rectification of Plant Alarm Setpoints

To enhance the performance evaluation of the plant alarm system, it is necessary to rectify the setpoints based on the operational data derived from actual plant or the simulation results of the dynamic plant simulator. Fig. 4 shows a trend graph of L1 during 80 minutes after the Mal-3 occurred. The normal value of L1 is 2.20 in a steady state, and the initial setpoint value for L1.PL is 2.09 mentioned in Table 2. The setpoint value of L1 should be set as higher than or equal to 2.09 in order to activate alarm signal L1.PL within t_a (=42 min.) against a similar magnitude of Mal-3. The following inequality is derived:

$$\text{L1.PL} \geq 2.09 \tag{4a}$$

Fig.5 also shows the trends of L1 with different 4 magnitudes of Mal-3. Mal-3a is the same with the trend in Fig.4. And the inequality constraints are derived as follows:

$$\text{L1.PL} \geq 2.06 \tag{4b}$$

$$\text{L1.PL} \geq 2.03 \tag{4c}$$

$$\text{L1.PL} \geq 2.14 \tag{4d}$$

In addition, the following inequality constraint is derived because the low limit setpoint should be smaller than the normal values.

$$\text{L1.PL} < 2.20 \tag{5}$$

As a consequence, equation (6) is derived as the allowable range, because equation (4d) is the tightest constraint between inequalities 4a–4d.

$$2.14 \leq \text{L1.PL} < 2.20 \tag{6}$$

In the same manner, the following constraints for each alarm signals are derived.

$$5603 < \text{F1.PH} \leq 5876 \tag{7a}$$

$$5315 \leq \text{F1.PL} < 5603 \tag{7b}$$

$$2.20 < \text{L1.PH} \tag{7c}$$

$$77.7 < \text{V4.PH} \leq 81.6 \tag{7d}$$

$$73.8 \leq \text{V4.PL} < 77.7 \tag{7e}$$

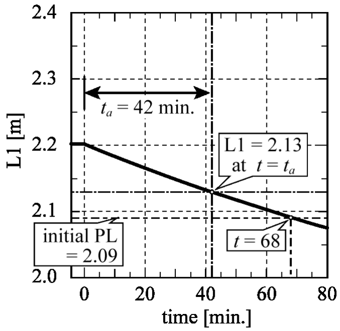

Fig. 4. Trend graph of L1 with Mal-3.

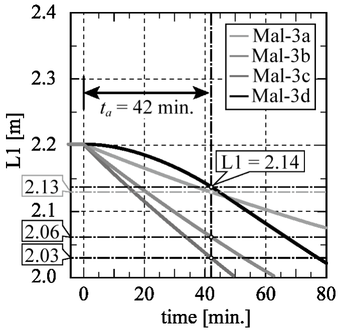

Fig. 5. Trend graph of L1 with various magnitude of Mal-3

3.5 Verification of Rectification of Plant Alarm Setpoints

Table 4 shows a set of rectified setpoints within the allowable ranges mentioned in section 3.4. The setpoints of F1.PH, F1.PL and L1.PL were changed. Table 5 shows the activation times, t_e and the evaluation values. As compared with Table 3, all of the distinguishable alarm signals have been activated within t_e for all the malfunctions. Therefore, all the performance evaluation values—effective, recall and timeliness rates— are improved to 100 %.

Table 4. Rectified alarm setpoints.

Measured variables	F1 [kg/hr]		L1 [m]		V4 [%]	
Normal values	5603		2.20		77.7	
Signals	PH	PL	PH	PL	PH	PL
Initial setpoints	*5827	*5379	2.31	*2.14	81.6	73.8

Table 5. Alarm activation times for each assumed malfuntions with rectified alarm setpoints

	t_a [min.]	Alarm signals	Activation times [min.]	t_e [min.]	Evaluations		
					Effective rate	Recall rate	Timeliness rate
Mal-1	129	F1.PH	0	0	100%	100 %	100 %
		L1.PH	104				
Mal-2	129	F1.PL	0	0	100 %	100 %	100 %
		L1.PL	55				
Mal-3	42	L1.PL	35	35	100 %	100 %	0 %
Mal-4	129	V4.PH	0	0	100 %	100 %	100 %
		L1.PL	79				
Mal-5	129	V4.PL	0	0	100 %	100 %	100 %
		L1.PH	129				

4 Conclusion

We proposed a determination method of plant alarm setpoints in accordance with the diagnostic and timely evaluations. Dynamic plant simulation results were used to demonstrate its feasibility.

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Pilot Experiments in Education for Safe Bicycle Riding to Evaluate Actual Cycling Behaviors When Entering an Intersection

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Abstract. Previous studies have proposed educational methods to improve the basic driving behaviors of unsafe drivers by evaluating their actual driving behaviors. In this paper, we report on applying the teaching methods proposed by previous studies to a new method for bicyclists to improve their safe riding behavior and awareness. The results of our education experiments indicated that it was important for a rider to increase the chance of noticing a crossing bicycle by confirming safety by looking right and left. The participants did not have this knowledge before the education. After the bicycle riding simulation and education, they understood it was effective to confirm safety by looking right and left to decrease the risk of an accident.

Keywords: educational method, safe bicycle riding, cycling behavior, driving simulator.

1 Introduction

The number of traffic accidents in Japan has decreased recently, while the number of bicycle accidents has not. Typical bicycle accidents include crossing collisions between bicycles, between a bicycle and a car, or between a bicycle and a pedestrian at intersections in Japan [1]. Crossing collisions account for 50 percent of all bicycle accidents [1]. There are no riding assistance systems to prevent accidents, and an effective educational method for safe bicycle riding is required. Takemoto proposed a new educational method for car drivers using a driver model based on analysis of the driver's behavior when passing through an intersection and a simulation evaluating the driving behaviors [2]. We applied the teaching methods proposed by the previous study [2] to a new method for bicyclists to improve their riding behavior. In this paper, we report the pilot experiments in the new educational method for safe bicycle riding we conducted.

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 515–523, 2013.

2 Educational Method for Safe Bicycle Riding

Figure 1 shows an outline of the educational method for safe bicycle riding in this study.

First, an experiment in which a participant rides a bicycle and passes through an intersection is conducted to collect data such as bicycle speed and the rider's direction of glance while passing through the intersection.

Next, the collected bicycle speed and direction of glance in each bicycle position at the intersection are graphed. The participant can understand profiles of bicycle speed and direction of glance when he/she passes through the intersection by looking at these graphs.

A simulation in which a bicycle passes through the intersection is executed. Input data of the simulation is width of a rider's view at the intersection, bicycle speed and direction of glance collected in the experiment and map information of the intersection the participant passed through. In the simulation, a participant riding a bicycle passes through the intersection. The simulation has a crossing bicycle. The crossing bicycle has various conditions, initial positions of the bicycle and speeds while passing through the intersection. The simulation judges whether the bicycle ridden by the participant crashes into the crossing object at the intersection in each condition.

3 Experiment

3.1 Participants and Experimental Course

The participants in this study were six male college students 19-20 years old who volunteered for this experiment. All traveled to school by bicycle. Figure 2 shows an intersection selected for collecting data in the experiment. Five of the six participants passed through the intersection when they went to school and the remaining participant passed through the intersection once a week.

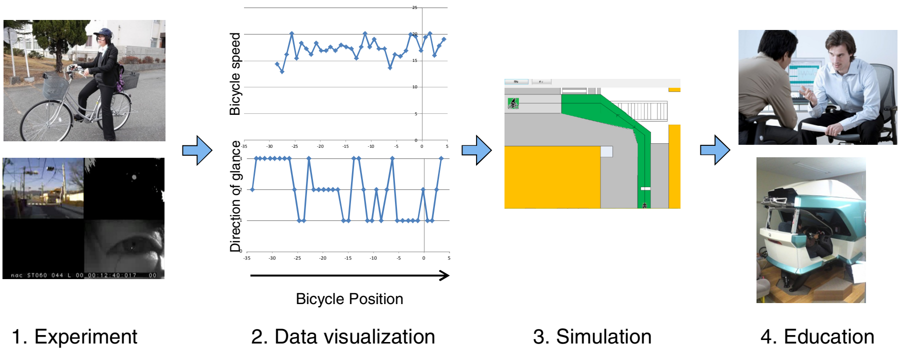


Fig. 1. Outline of educational method for safe bicycle riding

3.2 Apparatus

Figure 3 (a) shows the bicycle used for this experiment. The experimenter used an Eye Mark Recorder EMR-9 (NAC) to record an image of the front view of the rider and the direction of glance. Figure 3 (b) shows an example image recorded by EMR-9. A laser displacement meter LD90-3300 (RIEGL) was used to record speed of the bicycle while passing through the intersection.

3.3 Procedure

The participants rode the bicycle and passed through the intersection shown in Figure 2. We collected the speed of the bicycle and the participant's direction of glance while

Fig. 2. Selected intersection for experiment

(a) (b)

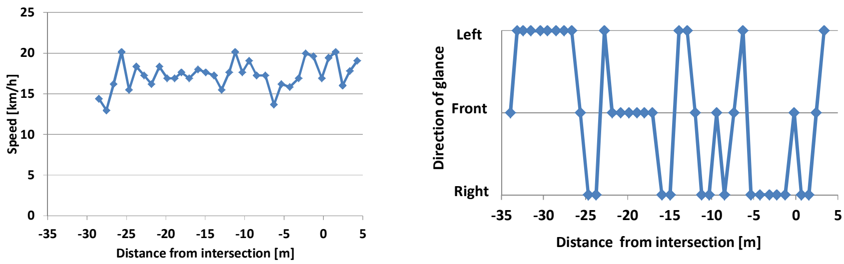
Fig. 3. (a) Bicycle for experiment and eye mark recorder (b) Image example recorded by eye mark recorder in experiment

passing through the intersection. The traffic light turned green and no objects such as cars, bicycles or pedestrians obstructed the passing of the participants through the intersection. The experimenter recorded the participant's speed and direction of glance when passing through the intersection.

3.4 Results

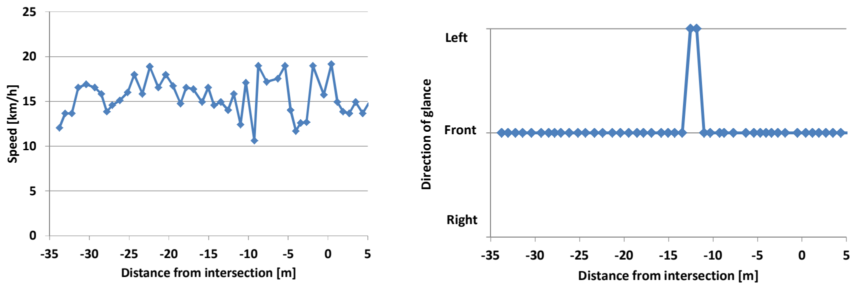
Figure 4 shows bicycle speed and direction of glance while participant D passed through the intersection. Figure 4 (a) shows that he rode the bicycle at a speed between 15 and 20 km/h before entering the intersection. This figure also shows that speed measurement error is large. The experimenter set his sights on the bicycle using the sighting device when the participant passed through the intersection. The setting of sights is difficult, and this was the main cause of measurement error. Figure 4 (b) shows that the participant glanced left four times before entering the intersection.

Figure 5 shows bicycle speed and direction of glance while participant E passed through the intersection. Figure 5 (a) indicates that he rode the bicycle at a speed of between 10 and 20 km/h before entering the intersection. Figure 5 (b) indicates that the participant glanced left only once before entering the intersection.



(a) Speed of bicycle (b) Direction of glance

Fig. 4. Speed of bicycle and direction of glance while participant D passed through intersection



(a) Speed of bicycle (b) Direction of glance

Fig. 5. Speed of bicycle and direction of glance while participant E passed through intersection

Table 1. Average speed, number of times used to confirm by looking left and time used to confirm by looking left while participant passed through intersection

Participant	Average speed [km/h]	Number of times used to confirm by looking left	Time used to confirm by looking left [s]
A	18.2	1	1.2
B	20.5	4	2.4
C	17.3	2	1.0
D	17.5	5	2.6
E	15.0	1	0.4
F	19.6	1	0.4

Table 1 shows average speed, number of times used to confirm by looking left and time used to confirm by looking left while the participant passed through the intersection.

4 Simulation to Pass through Intersection

We created a simulation program to visualize the risk of a bicycle rider in various potentially hazardous situations by changing the speed and initial position when the rider passed an intersection. We simulated a bicycle ridden by a participant passing through an intersection in the presence of a crossing bicycle.

Figure 6 shows a displayed image of the program. Input data of the program is bicycle speed, the direction of the glance of the participant as shown in Figure 4, and the degree of the participant's view on the left side at each of the participant's positions while passing through the intersection. We assumed that initial position of the crossing bicycle was 10 m, 15 m and 20 m from position X in Figure 6. We also assumed that the speed of the crossing bicycle was the same as the average speed of a bicycle ridden by a participant, 4 km/h faster than the average speed, 8 km/h faster than the average speed and 12 km/h faster than the average speed. The number of combinations of the initial position and speed of the crossing bicycle was 12. We simulated the 12 combinations for each participant, and counted the number of accidents between the crossing bicycle and the bicycle ridden by each participant in the simulation.

Table 2 shows the simulation results. Participants A and D caused no accidents. Table 1 shows that they confirmed safety by looking left relatively longer while passing through the intersection. Table 1 also shows that Participant B confirmed safety by looking left relatively longer and more times, but he caused an accident once. We assume that this is because the average speed of Participant B was 20.5 km/h, the fastest of all the participants. These results indicate that it is important for a rider to increase the chance to find a crossing bicycle by confirming safety by looking right and left, and to reduce the speed of the bicycle while passing through an intersection to prevent intersection accidents.

Based on the above, the main targets of our education on safe bicycle riding were participants B, C, E and F, who caused accidents in the simulation. We made it our main educational policy to help participants C, E and F understand that improving confirmation of safety by looking left will decrease the risk of accidents. We also made it our policy to help Participant B understand that reducing the speed of the bicycle is necessary to decrease the risk of accidents.

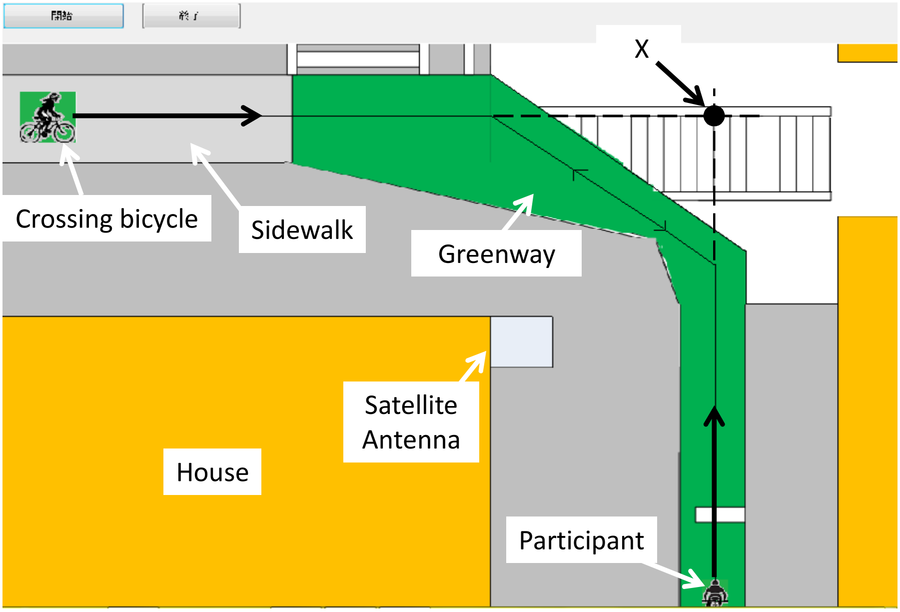


Fig. 6. Displayed image of simulation program

Table 2. Number of accidents in simulation

Participant	The number of accidents
A	0
B	1
C	4
D	0
E	5
F	6

5 Trial Safe Bicycle Riding Education

5.1 Procedure

We tried to educate the participant to improve his safe bicycle riding awareness. The following education procedure was conducted for the participant.

1. The experimenter questioned the participant about the following items:
   - Knowledge of traffic rules about riding a bicycle.
   - Safe riding behavior and awareness when passing through an intersection.
   - Safe riding behavior and awareness when passing through the intersection where the experiment was conducted.
2. The participant watched the following video images:
   - one in which the experimenter recorded the participant's eye movements and the front view while he passed through the intersection,
   - one of the intersection when the participant passed through it.
3. The experimenter showed the graph of bicycle speed and the direction of glance such as Figure 4 while the participant passed through the intersection.
4. The experimenter showed the participant the simulation images and results in his case. We showed participants B, C, E and F the following two cases of simulation results.

   - A case where the participant caused no accidents when entering the intersection. Speed of the crossing bicycle was same as the average speed of the bicycle ridden by the participant.
   - A case where the participant caused an accident when entering the intersection.

5. The experimenter explained the difference between the two cases and the reason the participant caused the accident. We also explained that improving confirmation of safety by looking left decreased the risk of accidents.
6. The participant drove a car on the driving simulator and encountered a bicycle at a blind spot that suddenly crossed the path of the car driven by him. After this, the experimenter explained to the participant that there was a case where it is difficult for a driver to see a bicycle while driving, and the driver caused an accident.

5.2 Results

All the participants answered that it is effective to reduce speed to prevent an accident between bicycles at an intersection, and that improving confirmation of safety by looking right and left is not effective in the questionnaire in 5.1. The simulation results showed that improving confirmation of safety by looking left decreases the risk of accidents. These results indicated that the knowledge that improving confirmation of safety by looking right and left is effective for decreasing the risk of accidents is new and important information for the participants.

All the participants also answered that they caused no accidents or could avoid an accident between bicycles at the intersection where the experiment was conducted in their usual riding behavior. Participants B, C, E and F subsequently understood that they might cause an accident between bicycles at the intersection under some conditions from the simulation results.

After this education, all of the participants answered that they did not know that improving confirmation of safety by looking right and left decreases the risk of accidents, and understood that from the simulation results using their riding behavior data.

In procedure 6 in 5.1, all of the participants who drove a car on the driving simulator could not find the bicycle and caused an accident. The participants understood that car drivers cannot always see bicycles nearby and cause an accident. This knowledge is new for the participants who have never driven a car before. We expect that their understanding of this fact will motivate them to improve their confirmation of safety by looking right and left voluntarily.

6 Conclusion

In this study, we conducted pilot experiments in a new educational method for safe bicycle riding. First, we conducted an experiment to collect the participants' riding behavior while passing through an intersection. Second, we simulated the participants passing through the intersection in the presence of a crossing bicycle under various conditions. The results indicated that it was important for a rider to increase the chance to detect a crossing bicycle by confirming safety especially by looking right and left. Finally, we conducted safe bicycle riding education to improve the participants' safe bicycle riding awareness. The participants came to understand that it is effective to confirm safety by looking right and left to decrease the risk of an accident.

Future research will improve the educational method. We will also increase the number of participants and verify the effectiveness of our education method.

Acknowledgements. The authors would like to acknowledge Terunao Nakayama, a former student of Nara National College of Technology, who assisted in carrying out the experiment and the simulation. This work was supported by JSPS KAKENHI 23500833.

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Task Analysis of Soft Control Operations Using Simulation Data in Nuclear Power Plants

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Abstract. Soft control is one of the major characteristics of advanced main control rooms (MCRs) in nuclear power plants, which have been recently developed using digital and computer technologies. Various kinds of advanced MCR designs have been proposed with their own features, and every design has advantageous and disadvantageous effects on operator performance. In this work, to observe operator behaviors using soft controls, the simulation data were analyzed. The analysis results showed that the interface management tasks occupy a large portion compared to the primary tasks in providing control inputs to the devices. These additional tasks required for performing an operation cause further possibility of human errors. Therefore, it is necessary to design an interface that can optimize the additional tasks for preventing errors. Through human error analyses for interface designs, a more human error preventive design is achievable.

Keywords: Soft Control, Human error, Advanced main control room.

1 Introduction

The operational environment of main control rooms (MCRs) in nuclear power plants (NPPs) has been changed significantly by the adaption of digital and computer technologies. Advanced MCRs (or computerized MCRs) have totally different interfaces from conventional analog MCRs and the methods used to monitor the plant status and control and maintain the plant are also different. Advanced MCRs are usually designed using a large display panel (LDP), computer displays, soft controls (SCs), and computerized operator support systems, such as a computerized procedure system (CPS) and an advanced alarm system. Fig. 1 shows an example of advanced MCRs [1]. With the change in operational environment, human errors of MCR operators should be re-analyzed as different human error modes and occurrence probabilities may occur. Before adapting newly designed interfaces to plants, system validation and operator performance analyses should be performed. Advanced MCRs can have not only positive effects but also negative effects on operator performance: human error probability can increase or new types of human errors may be created [2]-[5].

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 524–529, 2013.

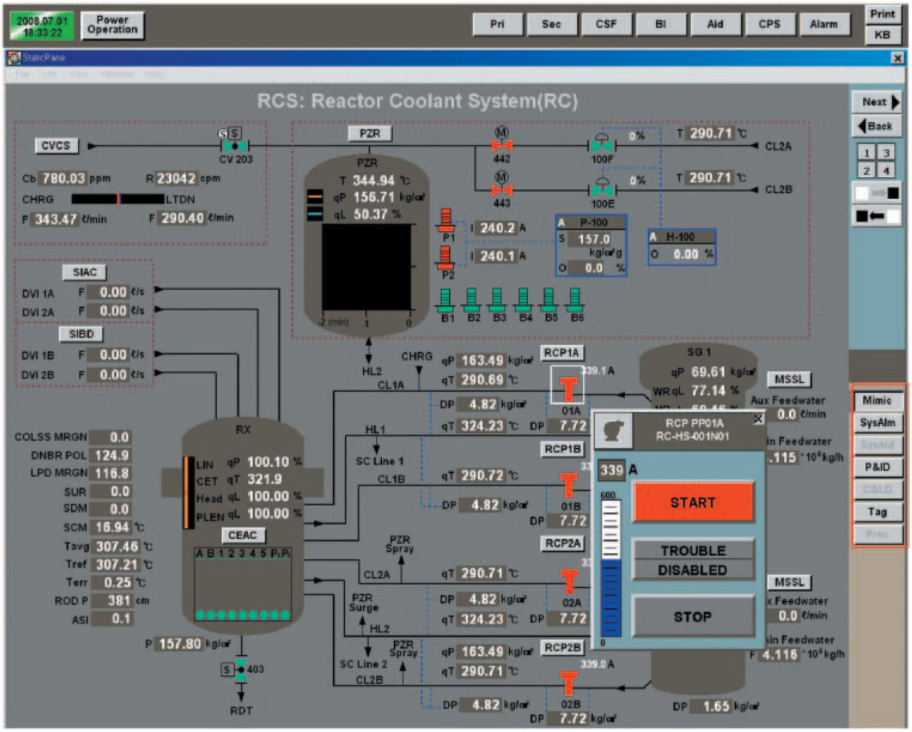

Fig. 1. The interface of the APR1400 MCR [6]

2 Secondary Tasks for Interface Management

The tasks in advanced MCRs are mainly categorized into two types: primary tasks and secondary tasks. The primary tasks indicate the controls to provide control inputs to plant systems (e.g., opening/closing valves and starting/stopping pumps). The secondary tasks are mainly related to the interface management. Operators have to manipulate the user interface to access information or controls, or to change the control modes. These kinds of tasks required before performing primary tasks are called secondary tasks (e.g., navigating screens and handling different types of input devices). While conventional MCRs do not have secondary tasks, the secondary tasks take a relatively large portion. The different operational environment including these additional tasks could cause new types of human errors or can vary the possibility the errors. Secondary tasks are one of the general characteristics of the advanced MCRs, and also major differences from conventional MCRs. If only primary tasks are considered for an SC task analysis, the analysis is not much different from conventional controls.

One of the special features of computerized MCRs is 'design flexibility', as they are designed using software and computer screens [6]. The types of input devices, methods to control the devices and navigate the screens, and methods to display plant information or feedback of an action are designed differently. For example, SCs can be designed with only one input device type or with a combination of multiple input device types. A well-organized input interface can reduce human errors by optimizing the workload and task complexity and enhancing the situation awareness ability. Handling all controls with one input device may reduce the required tasks. On the other hand, multiple input devices may make an operation more complex because an operator has to handle different input devices according to the tasks. However, different types of controls (e.g., different input devices on different systems or safety class components) may require more attention by operators or the operators may easily recognize which components they are handling. In some plants, for another example, an informative design is preferred, and a lot of information is displayed on a screen. On the other hand, an optimized amount of information is preferred in some plants even though more screen navigations are required. Since computer screen displays have a hierarchical structure and the total amount of information that should be shown on the screens is the same, less screen navigations are required in a more informative interface design to search for a component. However, an informative screen design may cause a high workload of an operator to find a component on a screen.

3 Simulation Data Analysis

The simulation data were analyzed to observe the SC tasks in this work. The simulation data were obtained from the APR-1400 MCR simulator and the simulation conditions are as follows:

- Simulator: full-scope simulator for the APR-1400
- Operators: five teams consisting of SS (shift supervisor), RO (reactor operator), TO (turbine operator), EO (electric operator), and STA (shift technical advisor)
- Scenarios: LOCA (loss of coolant accident) and SGTR (steam generator tube rupture)

The simulation was recorded by four camcorders. The camcorders recorded the overall MCR, SRO, RO, and TO. In the analysis, only RO and TO data were considered because the SC operations are mainly performed by RO and TO in LOCA and SGTR scenarios. SRO mainly handled the CPS and gave orders to the other operators. Also, the amount of the EO tasks was relatively small in the given scenarios. Several methods were used to estimate the performance of operators, such as questionnaires, a communications analysis, and a video analysis. In this paper, only the number of performed tasks obtained by a video record analysis is described.

The limitations of the simulation are as follows:

- The operators have sufficient experience for conventional MCRs but do not have much experience on advanced MCRs.
- Only two scenarios are considered.

- The simulation has a different operational environment from a real accident situation with regard to the workload, stress, decision burden, and so on.
- The given scenarios to all operating teams are the same. However, according to the knowledge and strategy of each team, the procedure and operations performed were different.

In the simulator, the primary tasks consist of binary and continuous actions. The binary actions indicate pressing one of two buttons such as 'OPEN/CLOSE' or 'START/STOP.' The actions such as setting a set-point or water level are performed through continuous actions by pressing arrows (e.g., ︽ ︿ ︾ ﹀). Secondary tasks include the interface management tasks; 'opening/closing a control panel', 'pressing acknowledge button', and 'changing screens'. An operator opens a control panel for a device by selecting the device with a mouse. If the selected device is related to safety-related components, the operator is then required to press an acknowledge button (channel confirmation button) before performing the primary tasks. In this case, the primary tasks are performed in the independent control panel screen located below the monitoring screens. If the selected device is a non-safety component, the control actions are executed through a pop-up control panel in the monitoring screen. Operators switch their personal display screens using screen selection/navigation buttons on the screen. Also, the CPS used in the simulation provides the screen link buttons located in the below steps, which load the corresponding screen to the current step on the monitoring screen.

Fig. 2, Fig. 3 and Fig. 4 show the results of the simulations. The followings are observed in the analysis result:

- As shown in the graphs, the number of secondary tasks is greater than that of primary tasks in almost all cases. The average number of primary tasks is 19.7 for RO and 52.1 for TO, but the average of secondary tasks is 60.3 for RO and 89.2 for TO. The ratio of primary tasks is 24.6%, and that of secondary tasks is 75.4% for RO. The ratio of primary tasks is 36.9% and that of secondary tasks is 63.1% for TO.
- The number of performed secondary tasks between teams cannot be simply compared because different operations were performed based on the expertise and knowledge of each team. Even when the same operation is performed, the counted actions were quite different at times. However, in almost all cases, the number of secondary tasks is greater than that of the primary tasks, and it can be said that operators should handle lots of interface management tasks to perform the primary tasks.
- Among the secondary tasks, as shown in Fig. 4, the portion of screen navigation is large. The amount of screen navigation is varied according to the expertise and familiarity with the interface and system of the individual. While some operators spent a lot of time to reach the screen they wanted to see, some operators efficiently used the corresponding screen link buttons of the computerized procedure system and optimized the amount of secondary tasks.

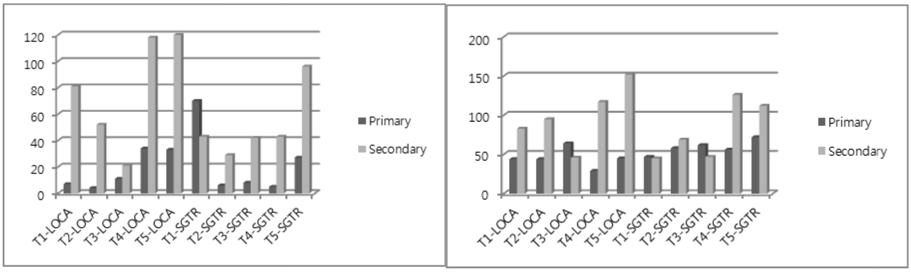

Fig. 2. The number of primary and secondary tasks

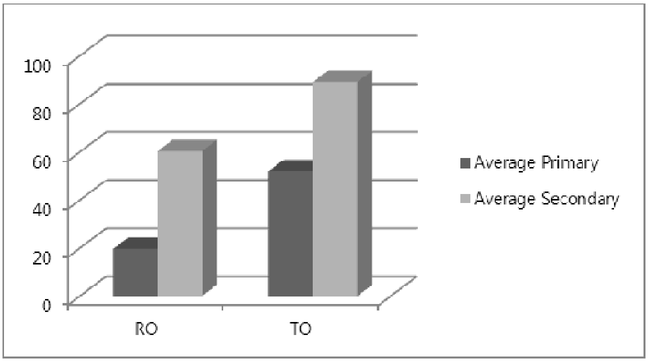

Fig. 3. The average number of primary and secondary tasks

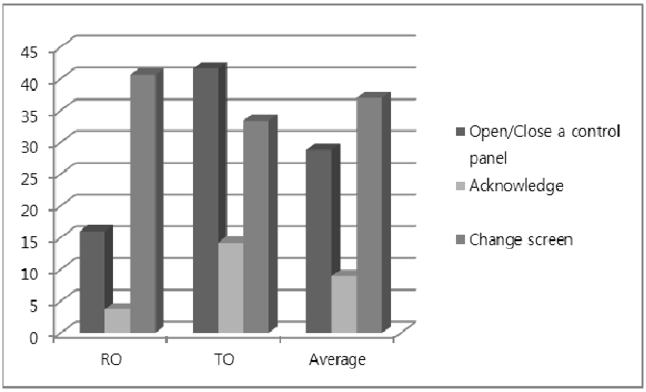

Fig. 4. The contribution to the secondary tasks

4 Conclusions

Digitalized MCRs can be designed with high design flexibility, and each design may have advantageous and disadvantageous effects on the operator performance. SCs are an important issue for a human error analysis for advanced MCRs. In this work, to observe operator behavior during SC operations, the simulation data of the APR-1400 MCR, which is a recently developed, was analyzed. In the analysis results, it was observed that the portion of secondary tasks is quite large compared with that of the primary tasks.

Even though the simulation data are not sufficient to observe human errors and quantify them, it was observed that there is a trend of operator behavior with regard to the primary and secondary tasks. In almost all cases, operators performed more secondary tasks than primary tasks, in particular, the portion of screen navigation is large. It should be noted that the operators in this experiment are not sufficiently familiar with the computerized interfaces. Some secondary tasks can be caused by their inexperience. Some operators executed unnecessary interface managements unintentionally, or did so intentionally to be familiar with the interfaces. If they are trained for years and have sufficient experience, they may be able to manage the interface efficiently and the number of secondary tasks may be optimized. However, even though the unfamiliarity of operators is considered, the number of secondary tasks was much greater than that of the primary tasks, usually about two fold. When the operators have experience of an interface, the secondary tasks can be reduced, but it is expected that the secondary tasks will be occupy quite large portion of all tasks.

Simulation data that are currently available are used in this work. When sufficient operational experience of advanced MCRs is accumulated, a more reliable analysis will be performed.

Acknowledgements. This research was supported by a Nuclear Research & Development Program of the National Research Foundation (NRF) grant funded by the Korean government. (Grant Code: 2012-011506).

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A Semiotic Based Method for Evaluating Automated Cockpit Interfaces

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Abstract. Issues of Human-Machine Interaction in the aircraft's cockpit are well known as causes of events that collaborate with material and human losses. In this scenario, the design and evaluation of interfaces must follow rigorous methods. The objective of this work is to develop an evaluation method of Human Computer Interaction (HCI) within the cockpit in order to reduce erroneous actions. This method is based on theories and techniques from the Organizational Semiotics (OS) field. The feasibility of the proposed method was investigated in a case study in an aeronautical simulated scenario with the participation of three pilots. The intention is contribute to the advancement of knowledge in HCI cockpit environment, particularly in the understanding of human factors related to semantic, pragmatics and the situational awareness aspects of the interaction with computing devices, as well as creates a feasible method to evaluate these factors during the execution of the mission' tasks.

Keywords: Safety Systems, Interface Evaluation, Semiotics.

1 Introduction

Cooperation between the human being at the aircraft cockpit and the cognitive assistant system creates a "mental mode" that must be clearly, steadily and readily assimilated. Under common fairly or stringent demands allows the expressed a strong preference of the human in the command of an aircraft for a management by consent approach where the automation system cannot take any action until the explicit consent from whose is in charge in the aircraft's cockpit mission.

The research for innovative evaluation methods imposes challengers to the Human Computer Interaction (HCI) studies. Such methods should consider alternatives for the evaluation of aspects unexplored in HCI. Multidisciplinary approaches, such as semiotics and human factors in HCI, may provide valuable insights to the advance of cockpit interface evaluation.

The human factors studies are first interested in the role and position given to the end user in the system. Human factors cannot be restricted to a list of local ergonomics principles, such as shapes, colors or information flow; it first refers to a

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 530–539, 2013.

philosophy of human-machine coupling, giving the central role to human. Suppose a system in which the crew should be a simple executor, with a perfect instrument panel allowing a total comprehension, but without any possibility to deviate from orders, and with a permanent and close electronic device overriding crew decisions. Such a system should no longer be considered as corresponding to a satisfactory human factors design. The crew cannot have a second role because the members continue to be legally and psychologically responsible for the flight. They must keep the final authority for the system. Luckily, crews still have the authority with the aerodynamics flying parameters from the glass cockpits information such as speed, altitude and aircraft´s attitude like pitch down or climbing or intended leveled flight. But the tendency of technique is clearly to cut down this privilege.

Nowadays, some limited systems already override the crew decision in certain circumstances (e.g., for flight or engine protections). The goal of the human factors community is to improve the value associated with these systems, not to enter into a debate on the safety balance resulting of these solutions (as usual, we know how many accidents/incidents these systems have caused, but we ignore how many incidents/accidents they have contributed to avoiding). However, how far can we go in this direction with crews remaining efficient and responsible in the flight loop and with a satisfactory ethics of human factors? We must acknowledge that a human factor has no solutions for an infinite growth of system complexity. Therefore, if we want the crew to remain in command, either we have to limit the increasing human-machine performance until the research comes up with efficient results preserving the authority of humans, or we accept designing systems, for example, made with two envelopes: (1) The first envelope is controlled by crews. Within this envelope, crews are fully trained to comprehend and operate the system. They share full responsibility, have full authority and can be blamed for unacceptable consequence of their errors. (2) The second envelope or outside of the first envelope, the system enters into full automatic management guided by standardized parameters approved and validated by aeronautics authorities. In such a case, the technical crews are just passengers as all the others in the interior of the fuselage. In such case, human factors are not concerned, except for the transition from one envelope to the other one. Last, ergonomics and human factors only tailor the first envelope.

This paper reports both and ambiguous scenarios that intend to reach the equity between the computational resources and the human capacity to take the fly control safely to the destiny. Our hypothesis is that semiotics and affordances theory can support us in understanding the patterns of behavior made possible by the combination of the artifact (automated cockpits) and the human being (crews). By understanding and modeling (in a chart) the affordances, relations and norms during a takeoff scenario, we expect to produce an initial proposal of a method that is used as basis for questioning systematically how each affordance are possible by the combination of the crew and the automated system in each situation.

The paper describes a method to evaluate the issues of data integration and credibility via employing ontological model in the analysis of the interpretation of signs and the expected crews' behaviors in critical cockpit management. The evaluation method is based on Gibson´s [1] affordances concept expanded by Stamper in the

Semantic Analysis Method (SAM) and the Norm Analysis Method (NAM) [2]. The objective is to identify the affordances, as well as ontological dependencies and norms of the cockpit context. The core of this evaluation method proposal is the analysis of the capacity of the human being in taking the control of the machine artifact as necessary. This leads to a careful analysis of the interaction between pilots and the automated systems according to the expected patterns of behaviors.

A case study illustrates the application of the method in the analysis in a cockpit design. The analysis was performed in participatory sessions with three domain experts (experienced pilots) and points out the possibilities and the limitations of the evaluation method, as well as further research.

This paper is structured as follows: the second section presents the theoretical and methodological background; the third section presents the evaluation method; the fourth section presents the case study settings, including its context, and discusses its results, and the fifth section concludes the paper.

2 Background

This section presents key concepts, theories and methods adopted in this paper. The subsection 2.1 presents studies in situation awareness, and the subsection 2.2 introduces the OS field including SAM and NAM.

2.1 Aircraft Cockpit Situational Awareness

Situational awareness can be understood as the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and a projection of their status in the near future [3].

In a cockpit, Situational Awareness refers to the state of the crewman understanding of the process and relevant aspects of a dynamic environment in an aircraft cockpit with which a person is interacting. Optimum Situation Awareness requires knowledge of, for example, current process parameters and the normal value of those parameters, the difference between current values and normal values, the past state of the process and the predicted future state of the process. Situation awareness is maintained by integration of this information and is thus critical when the operator is confronted with a complex and changing situation. It is directly related to operator performance and is especially important during abnormal conditions when the operator is required to make correct diagnoses of faults and to identify situations and problems not covered by normal operating procedures. There have been several proposals on how to analyze situation awareness and how to design human-machine interfaces to optimize situation awareness so that the probability of human error is reduced. Research has shown that situation awareness is affected by many cognitive factors, by motivation and by workload. In particular, it has been suggested that the way information about the dynamic environment is represented in the operator's mental model plays a significant role in anticipation of certain events and thus a conscious attention and search for information. There is also common agreement that the work situation in complex modern aircraft control environments is characterized by high information content, which, if not managed properly, may contribute to excessive workload and hence operator error.

Semiotics may provide theories and methods to analyze situation awareness in the cockpit. The key argument is that an analysis of the nature, role and composition of signs within the cockpit design is crucial to understand the situation awareness [4].

2.2 Organizational Semiotics

Semiotics, as the study of signs and meaning, has influenced many HCI theories and methods. According to Peirce's approach [5], a sign can be seen as having three functions: representation (the form that the sign takes, called the representamen), its referent (that to which the sign refers, called the object) and its meaning (the sense made of the sign in the operator's mental model, called the *interpretant*).

The OS discipline studies the nature, characteristics, function and effect of information and communication in the organizational contexts. Organization is considered a social system in which people behave in an organized manner by conforming to a certain system of norms [6], from this perspective a cockpit can be studied as organizations, once it is demand (very) organized behavior.

Among the methods employed by the OS community is a set of methods known as MEASUR (Methods for Eliciting, Analyzing, and Specifying Users' Requirements) [2]. The SAM is one of the MEASUR methods which focus on the agents and their pattern of behaviors. Some basic concepts of OS adopted in this work are based on Liu [6] and Stamper [7]:

- "An agent" is defined as something that has responsible behavior. Some examples in context of this paper are: a pilot, a co-pilot, an airport authority and a crewman.
- "Affordance", the concept originally introduced by Gibson [1] to express the behavior of an organism made available by some combined structure of the organism and its environment, is extended by Stamper [8] to include invariants of the social world; social affordances arise from the norms we share with people around us. Stamper argues that reality as we know it was not constructed individually; it was created by cultural development during millenniums. For example, a cup is a human artifact whose use is not only possible because of its physical aspect but also because of its social affordances (children have learned to use it for drinking, instead of throwing it at someone). In this sense, the yoke (control column) is not only possible/usable by it physical aspects but also because the pilots have learned to use it according to a set of norms.
- "Role-name" is the role of the agents according to the affordances that they are in charge. For example, a "pilot" is a crewman who is responsible for controlling the aircraft.
- "An ontological dependency" is formed when an affordance is possible only if certain other affordances are available. For example, the airplane "takeoff" is only possible if the airplane is in "acceleration".

The concepts of Semantic Analysis are represented by means of ontology charts, which have a graphical notation to represent agents (circles), affordances (rectangles), ontological dependencies (lines drawn from left to right), role-names (parentheses) and whole-part relations (dot).

In addition to the SAM, the NAM is used to describe the relationships between an intentional use of signs and the resulting behavior of responsible agents in a social context. At the social level, norms describe beliefs, expectations, commitments, contract, law, culture, as well as business [4].

According to Liu [4], the norms identified in NAM can be classified according to the human behavior in five types: *perceptual norms* (how people receive signals from the environment), *cognitive norms* (how people interpret and understand what is perceived), *evaluative norms* (how people attribute beliefs, values and objectives), *behavioral norms* (how people behave in regular patterns), and *denotative norms* (how people choices signs for signifying). The following example illustrates a behavioral norm description (using the formalism presented by [4]) in the context of this paper:

```
whenever the airplane is taxiing
if there is an holding position marking
then the pilot
is obliged
to wait for a permission to proceed;
```

3 The Semiotic Cockpit Evaluation Method (SCoEM)

The idea of the SCoEM is to constitute a checklist where each affordance and norm is evaluated with the artifacts that support the agents' action. The SCoEM does not impose or suggest methods to individually check each artifact feature, but it aims to be a framework to systematically apply the existing methods. Figure 1 presents an overview of the method, where the dashed lines delimitate the three phases:

1. *Participatory Ontology Charting*. During this phase HCI specialists work with domain specialists in the analysis and modeling of the affordances, ontological dependencies and other SAM's concepts. This phase is composed by three activities: (1.a) definition of the artifact(s) and the task(s)/procedure(s) to be evaluated; (1.b) description of the context, including procedures, tasks, artifacts and rules (guidebooks and manufacturer can be used in this activity); (1.c) application of the SAM, including candidate affordance generation, candidate grouping and ontology charting as described by Liu [4]. The activities 1.b and 1.c repeat iteratively until the ontology chart be validated buy the domain specialists;
2. *Participatory Norm Modeling.* During this phase HCI specialists work with domain specialists (e.g., pilots and instructors) in the analysis and modeling of all kinds of norms. This phase is composed by two activities: (2.a) the first activity is the detailed description in natural language of all affordances, in a way that we can detect the norms associated to them. These descriptions include the formal aspects,

as well as informal aspects related to the pragmatics and social context; and (2.b) the second activity is the application of the NAM, the norms are associated with the affordances detected in the last phase. These two activities are interactively performed until validate of all norms with specialists.

3. *Participatory Interface Evaluation*. During this phase affordances and norms are analyzed to elicit questions to be considered for evaluating with the domain specialists. Those questions are then verified using other HCI evaluation methods; typically, laboratory studies and simulation can be applied in this phase. This phase is composed by two activities: 3.a) in the first activity the affordances and other concepts from SAM are contrasted with the artifacts that are subject of the analysis; and 3.b) in the second activity the norms are contracted with the artifacts. The rationale is to evaluate all the artifacts and conditions necessary to perform the right actions according to the identified norms, for that a set of questions to be answered is derived from the norms. Suppose the evaluation of a device that automatically detects "holding position" in the airport taxiways, some examples of questions that arise from the norm described in the last section are: (1) Is the alert visible in the device? (i.e., perceptual norms), (2) Can the pilot properly understand the device alert? (i.e., cognitive norms), (3) How the pilots judge the value this type of device? Is it important? (i.e., Evaluative norms), (4) What is the expected behavior from the pilot using it the device? Can the device properly support it? (i.e., behavior norms), (5) Are the colors, shapes and other aspects properly used in the interface design? (i.e., denotative norms).

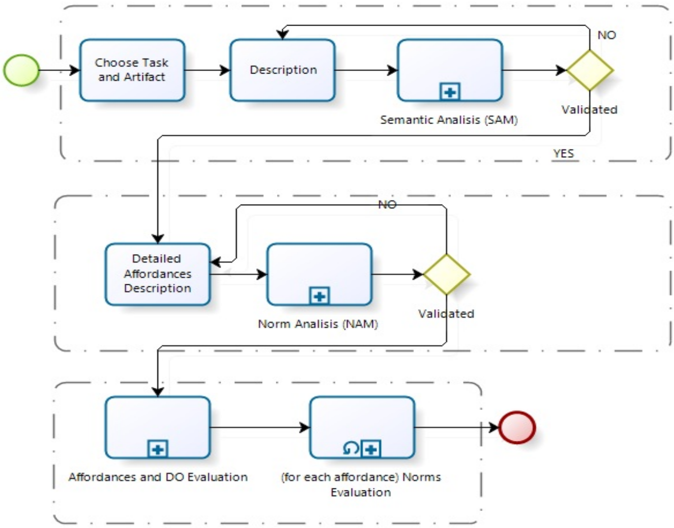

Fig. 1. Overview of the SCoEM

4 Case Study and Results Analysis

This study has been performed with tree experienced pilots in a real aeronautical media in a grounded pilot's instruction aircraft cockpit. The focus was the takeoff itself.

4.1 Case Study Context, Scenario and Pilot's Profile

The take-off of the "heavier than the air" artifact is one of the toughest things to do for the crewman in the cockpit, since the entire mass must face the earth gravity law that stuck everything on the surface. To reach the take-off endeavor the lift comes from the brakes release and engines thrust.

However, before the take-off, the aircraft must be pushed-back and taxi to the in use runway dictated by the airport authorities through a movement on the ground under its own power, up to the take-off phase of flight in which an aircraft goes through a transition from moving along the ground to flying in the air. The entire process of take-off starts after a call-out between the first-officer and Airport Authority controller under strictly sequential Norm Procedures on which the engine thrust is performed through acceleration in well known critical phases that were well trained by the crewman for thousand hours in a real flights even thou in the simulators.

The counter-part of the clear and logical activities sequence often generate subjective variables in the cockpit, showing an increased mental demand on the crewman performance as the robustness of the prioritization and allocation in the aeronautical "must to do" hierarchy such as fly the aircraft, navigate it and communicate your actions and intentions. The cognitive process mostly linked to the intuitive value judgments interfere in that process flow.

Figure 2 shows a Cessna 152 that was analyzed in this case study. It is a well known aircraft with demonstrated qualities for training proposes. In the left part of Figure 2 there is the cockpit numbered from one to 10 the relevant interface instruments, knobs and the necessary handled devices.

Fig. 2. Cessna 152

The study was performed three with the pilots with different profiles: (1) an airline instructor captain, (2) an agricultural professional pilot, and (3) a private pilot. All the pilots had already flown many hours in the Cessna 152.

4.2 Results and Discussion

As propose the SCoEM study started from a description of the take off task. An ontology char was constructed interactively with the pilots. Figure 3 shows an ontology chart with the key affordances (some aspects was omitted for reading proposes) involved in the takeoff tasks. The chart describe for example, that the *TakeOff* (at the right part of the diagram) is part of the *Flight* and is ontologically dependent of the *Acceleration*.

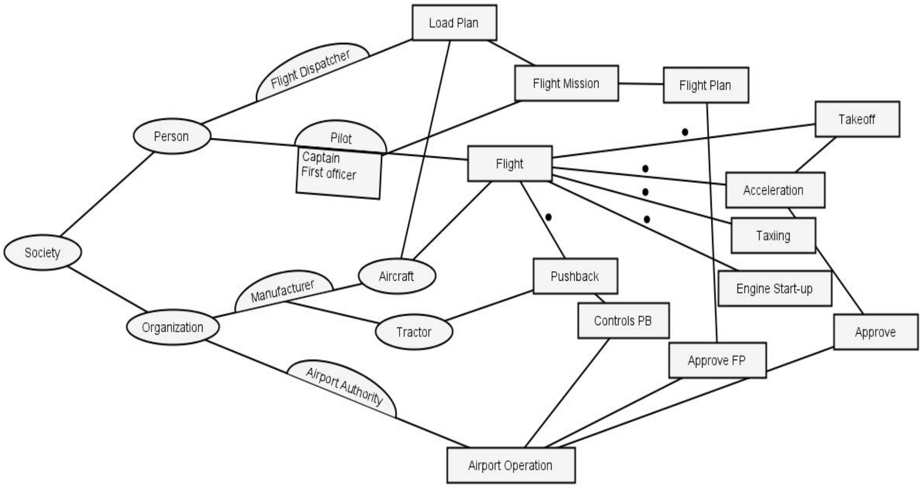

Fig. 3. Simplified takeoff ontology chart

After that, for each affordance a set of norm was elicited with the pilots. For example, 20 behavior norms describe the expected behavior of the pilots during the *Takeoff* affordance. The following norms are examples of behavior norms that the pilot follows during the *Acceleration:*

```
whenever the airplane taking off below V1
  if there is a critical failures
  then the pilot
  is obliged
  to abort the takeoff;
whenever the airplane taking off above V1
  if there is a critical failures
  then the pilot
  is obliged
```

```
  to continues the takeoff and returns for landing;
whenever the aircraft is still running on the runway
  if the aircraft´s does not reach the take-off speed up
     to the half of the runway length
  then the pilot
  is prohibited
  to still trying the take-off maneuver since its air
     speed data is unreliable
```

From the behavior norms a set of questions was elaborated, those questions expresses aspects related to the perceptual, cognitive, denotative and evaluative norms. For example, the following questions are related the behavior norms previous presented: (1) Are the warnings and alerts visible and audible?, (2) Do you feel comfortable with the instruments data?, (3) Are you always in the flight control?, (4) How you deal with the fuzzy dashboard pattern?, and (5) Cockpit noise and at least two ways radio communication is a stressful activity?

Table 1 presents a synthesis of the pilot's answers to these questions. The rows presents the pilot's numbers as described in the last sections, and the columns the perceptual, cognitive, denotative and evaluative aspects, as well as remarks that they judged important.

Table 1. Pilot's Answers

	Pilot´s Answers				
Pilot	Perceptual	Cognitive	Denotative	Evaluative	Remarks
1	1-Not all the alerts and warnings are visible 2- The radio sound is inaudible	1-We always strictly follow the aircraft´s manual and checklist guidelines 2-We just fly blind "computers numbers"	1-Radio sound level is good but the call-sign is not quite understood 2-The figures from the instrument is false due to the parallax reading error	1-The informed instrument data is logged as correct, but sometimes that´s not true	The professional pilot recognizes that the utmost embarked technology does not allow a free-error packet
2	The read instrument figures does not match with the real flight data	Heavy payload must be airborne through thrust and flying close to the ground	Not reported	1-The informed instrument data is logged as correct, but sometimes it is not true	The professional pilot reported a lot of false data came from the instruments such as real air speed
3	The read instrument figures does not match with the real flight data	Crosswind requires immediate corrective action at the takeoff maneuver	Two ways radio communication is embarrassing	The read take-off speed from the instrument does not match to the real speed	The pilot must collect the available flight data and decide to go on or not

In general, the results show important aspects to be taken in account during the cockpit evolution. The main limitation of the method concerns the granularity of the findings. For example, the answer "not all the alerts and warnings are visible" (Table 1) does not say too much about "why are they (the alerts) not visible?". A deeper investigation using HCI methods is needed to answer this question. On the other hand, despite this limitation (granularity), the SCoEM shows its potentialities of providing a systematic and well grounded way to elicit aspects to be evaluated in multiples perspectives, aligned to the expected pilots' behavior.

5 Conclusion

The Cockpit design demands rigorous and innovative evaluation methods due to it's critically for flight safety. This paper proposes the SCoEM, a participatory method based on semiotic concepts. Preliminary studies with three pilots with different profiles shows the potentialities of the SCoEM for allowing the aircraft designers and engineers finding out a balanced, ergonomically engineered automated interface allied to the semiotic tool contributing to understand and surpass the stringent flight rules.

The proposed method is a helpful manner to reach those demands and the near future supplementary aligned methods will improve it substantially. As the next steps we propose to the research of how HCI methods, such as ergonomy and cognitive ergonomy methods could be used to provide a fine grained explanation for the elicited problems.

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A Visual Discrimination Task for Symbols in Air Traffic Management

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Abstract. The present study explored the effectiveness of different symbol features in facilitating participants' ability to extract important information in visually-cluttered displays. Participants were presented with arrays of visual symbols consisting of a number of visual targets amidst distractor symbols. The participants had to decide as quickly and accurately as possible whether there were more targets or more distractors present in the array. Symbol features (color, fill, letter, and shape) were varied on a block-to-block basis, while set size and ratio of targets to distractors (easy/20:80 or difficult/40:60) were varied on a trial-by-trial basis. The results of this experiment revealed that search based on color gave rise to the best performance, while search based on shape gave rise to the worst performance. When selecting features that might aid in the rapid extraction of important air traffic information, the results of the present study suggest that the use of color coding may be most effective.

Keywords: symbology, air traffic control displays.

1 Introduction

The Next Generation Air Transportation System (NextGen) is an initiative to improve and upgrade the National Airspace System (NAS) in order to enhance the safety and efficiency of air transportation [1]. To achieve these goals, air traffic management (ATM) operations, airports, air operations centers, and flight decks are undergoing incremental changes in the equipment and technology that are required to allow for text-based communication, more precise navigation and prediction, and advanced decision support tools in the NextGen environment [2]. These tools and technologies can potentially help alleviate air traffic controllers' (ATCos) workload, allowing them to monitor and manage airspaces that may double or triple in capacity by the year 2025 [3-4]. It is important to note, however, that not all aircraft in an ATCo's sector are expected to be equipped with NextGen tools, at least in the near term, because of the costs associated with equipping aircraft with such technologies. Current day ATM is characterized by voice communications and a flight-plan-based ground system, while NextGen ATM is likely to be characterized by data communications and an en

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 540–547, 2013.

route, airborne flight management system. It is likely, therefore, that ATCos will have to manage mixed-equipage airspaces where some aircraft are equipped with NextGen tools and others are not. Moreover, it is also likely that a class of aircraft, those mainly flown in general aviation, will not be NextGen capable. In this mixed equipage environment, ATCos must be able to quickly identify aircraft characteristics in order to determine the specific controlling actions and procedures that can be applied to certain aircraft. As such, it is essential that ATCo displays be configured to provide information about the characteristics of individual and groups of aircraft currently in a given sector as rapidly and effectively as possible.

Symbols and icons, for example, are commonly used in ATM systems to convey important traffic information, such as location/position, direction of travel, alert level, and other information about the characteristics of individual aircraft. This information can be represented by a number of visual features, including shape, color, and size, to name a few. Air traffic controllers must be able to perceive and interpret the symbols in the context of radar displays, and make relatively quick judgments based on the information provided by the symbols in order to ensure the safe and efficient management of aircraft in their sectors. Surprisingly, relatively little attention has been paid to the design of displays and symbols for current ATCos (see e.g., [5-6]). The lack of standardization concerning the design and implementation of the appropriate symbols to use in order to most effectively convey important traffic information can lead to confusion, misinterpretation, and, ultimately, errors that can potentially be catastrophic. It is imperative, therefore, to determine early on which symbols and symbol features are most intuitive and/or easy to learn. At the very least, choosing standardized symbols can reduce the time spent learning the meaning of certain ATC symbols.

A number of studies have shown that certain symbol features and combinations of symbol features can be more quickly and effectively identified than others. For example, Chandra, Zuschlag, Helleberg, and Estes [7] found that the best symbols had clear direction indicators (e.g., a leading line or pointed head) and used conventional red or yellow colors to indicate alert level. McDougall, Tyrer, and Folkard [8] reported that simple symbols conveying two pieces of information were better than complex symbols conveying three of more pieces of information (see also [9-10]). Finally, Ahlstrom, Rubinstein, Siegel, Mogford, and Manning [11] found that ATCos favored color and graphical enhancements for reducing complexity.

The introduction of NextGen concepts and technologies in the NAS creates a unique opportunity to re-evaluate current day air traffic symbology and propose potentially new symbol features and designs. Just what features of symbols might best represent NextGen concepts and technologies, such as data link and self-spacing capabilities, are, as yet, unknown. We report on a study designed to test ATCo symbology and symbol features to determine their effectiveness in conveying important air traffic information. Participants were presented with arrays of visual symbols consisting of a number of visual targets amidst distractor symbols. The participants had to decide as quickly and accurately as possible whether there were more targets or more distractors present in the array. Symbol feature (color, fill, shape, and letter) was varied on a block-to-block basis, while set size and ratio of targets to distractors (easy/20:80 or difficult/40:60) were varied on a trial-by-trial basis.

2 Experiment 1

2.1 Method

Participants. Twenty-two students, ranging in age from 17 to 24 years (mean age = 19 years) from California State University Long Beach took part in this study and were awarded course credit for completing the experiment.

Stimuli and Apparatus. A computer with the software application E-Prime was used to program the experiment, present the visual stimuli, and to collect behavioral responses from participants. The visual target and distractor stimuli appeared against a black background. The targets and their corresponding distractors were green (RGB = 0, 255, 0) filled triangles amongst white filled triangles, white filled diamonds amongst white filled triangles, white filled triangles amongst white unfilled triangles, white capitalized Ss amongst white capitalized Ms, or white capitalized Ms amongst white filled triangles. Participants sat at a viewing distance of 60 cm. Each visual stimulus subtended approximately 1.15 ° of visual angle in length and .76° in width (see Fig.1).

Fig. 1. Illustration of symbols and features used in present study

Design and Procedure. Five target-distractor tasks (color: green triangles amongst white triangles, shape: diamonds amongst triangles, fill: filled triangles amongst unfilled triangles, letter: Ss amongst Ms, and letter-shape: Ms amongst triangles) were varied on a block-by-block basis and counterbalanced between participants. Two target-distractor ratios (easy - 20:80 or 80:20, and difficult - 40:60 or 60:40; see Fig. 2) and three set sizes (5, 10, and 15) were varied on a trial-by-trial basis and randomized within each block of trials. Each combination of target-distractor ratio and set size was repeated five times, resulting in 5 blocks of 60 trials each.

Participants gave their informed consent before beginning the experiment and verified that they had normal or corrected-to-normal vision. The participant then sat in front of a computer screen that was located in a dimly lit room. The participants were

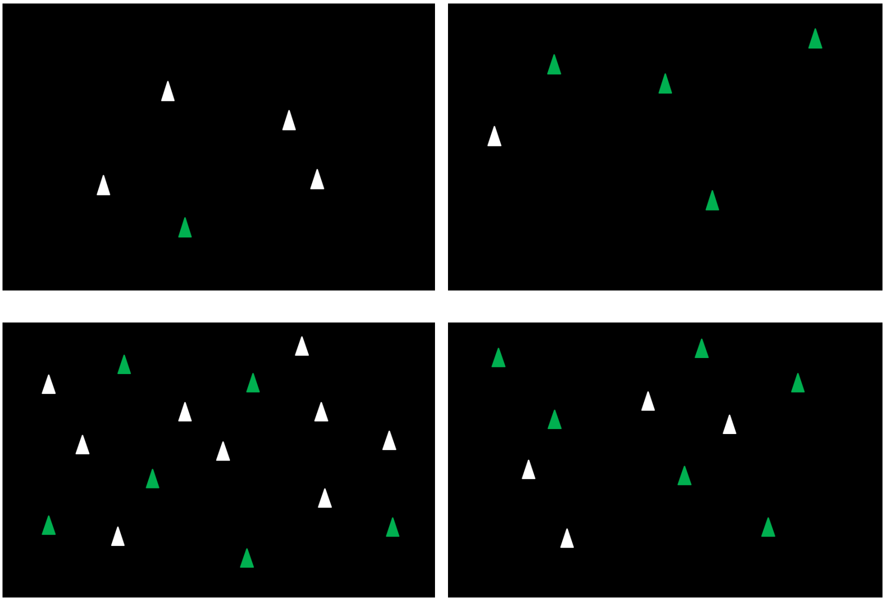


Fig. 2. Illustration of easy target-distractor ratios, 20:80 (top-left) and 80:20 (top-right), and difficult target-distractor ratios, 40:60 (bottom-left) and 60:40 (bottom-right)

instructed to keep their eyes fixated on a small fixation cross that appeared centered on the screen for 500 ms at the beginning of each trial. The participants' task was to determine, as rapidly and as accurately as possible, whether the visual search array contained more targets than distractors (by pressing the "y" key) or more distractors than targets (by pressing the "n" key). The targets and distractors were specified at the beginning of each block of trials. Participants were given feedback at the end of each trial in the form of a green "+" when they answered correctly, a red "-" when they answered incorrectly, or a white "o" when they did not give a response within 10 seconds of the onset of the trial.

2.2 Results

Participants' reaction time (RT) and accuracy data were recorded and converted into inverse efficiency (IE) scores to correct for any potential speed–accuracy trade-offs (see [12-13]). IE scores were computed by dividing each participant's mean RT for each condition by their proportion of correct responses for that condition. Greater IE scores reflect less efficient performance. A repeated measures analysis of variance (ANOVA) was conducted on the IE data with task (color, shape, fill, letter, or letter-shape), set size (5, 10, or 15) and ratio (easy or difficult) as the within-participants factors.

The main effects of task, set size, and ratio were all statistically significant, $F(4,84) = 42.55$, $p<.001$, $F(2,42) = 20.30$, $p<.001$, and $F(1,21) = 140.69$, $p<.001$, respectively.

The task X set size, task X ratio, and set size X ratio interactions were also all statistically significant, $F(8,168) = 7.32$, $p<.001$, $F(4,84) = 16.55$, $p<.001$, and $F(2,42) = 24.08$, $p<.001$, respectively. These main effects and two-way interactions were qualified by a significant task X set size X ratio interaction, $F(8,168) = 5.50$, $p<.001$ (see Fig. 3).

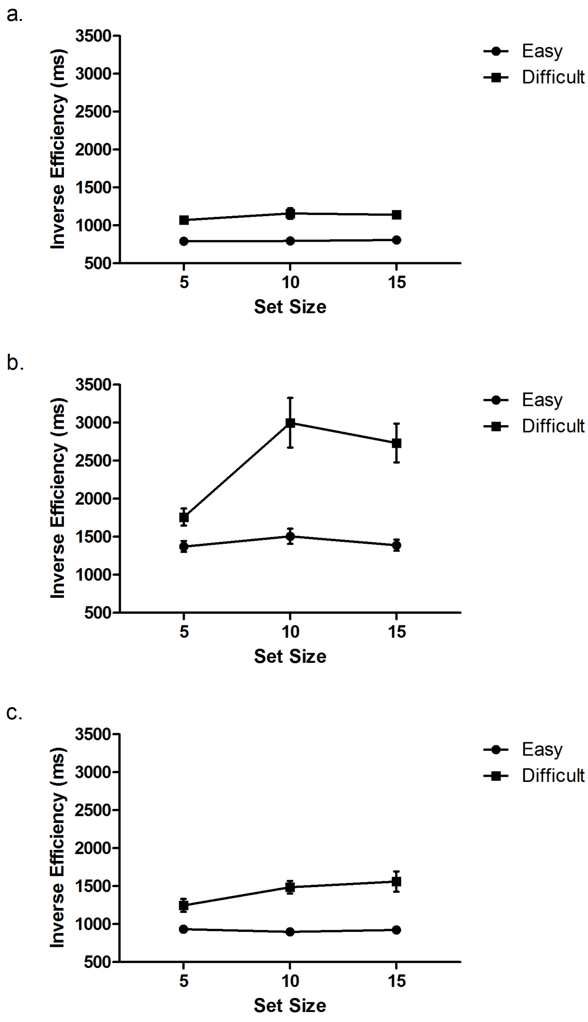
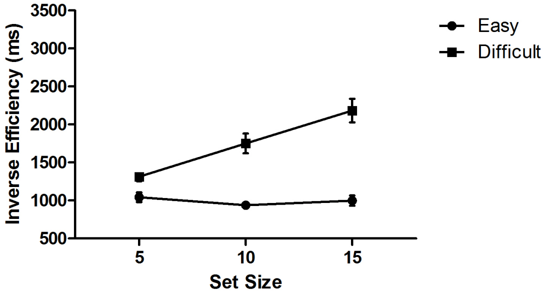


Fig. 3. Mean Inverse Efficiency (in ms) as a Function of Set Size and Ratio for a) color, b) shape, c) fill, d) letter, and e) letter-shape tasks

d.



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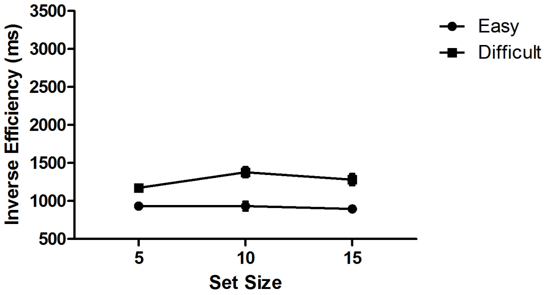

Fig. 3. (*continued*)

When the ratio was easy (20:80 or 80:20), set size had no effect on any of the tasks. Overall IE scores did, however, differ amongst the five tasks. Participants' IE scores were highest for the shape as compared to all other tasks. Participants also performed significantly better with the color as compared to the fill task. When the ratio was difficult (40:60 or 60:40), there was an effect of set size on the shape, fill, letter, and letter-shape tasks, with IE scores increasing as set size increased. The effect of set size was not significant, however, for the color task.

3 Discussion

The results of this study demonstrated that for tasks in which visual stimuli are distinguished by a single feature, it would appear as though color gives rise to the most efficient search, as compared to the other features of shape, fill, and letter. This was especially true when the target-distractor ratio was difficult. Distinguishing the target from the distractor symbols based on shape alone proved to be most difficult and time-consuming. When applied to the design of air traffic symbology for current day and NextGen operations, these results suggest that using various combinations of colors, fill, and letters may be a promising way of aiding ATCos in rapidly and effectively extracting important air traffic information.

4 Recommendations for Future Research

While color proved to be the most effective feature for discriminating between visual stimuli differing in a single dimension in the present study, it is unclear how color would fair when combined with other features. This is a particularly important area of research to further explore given the fact that multiple pieces of air traffic information may need to be conveyed in a single symbol. Moreover, more than two colors may typically need to be used in a given sector to distinguish aircraft based on a number of characteristics. In these environments, the benefits of color-coding may be diminished if the information conveyed by the colors is too complex or there is overlap in color usage for different aircraft characteristics (see, for example, [14-15]).

Acknowledgments. This project was supported by NASA cooperative agreement NNX09AU66A, Group 5 University Research Center: Center for Human Factors in Advanced Aeronautics Technologies (Brenda Collins, Technical Monitor).

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Influence of Deceleration Intention Indicating System of Forward Vehicle on Driver Behavior

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Abstract. This paper discusses a way to detect the driver's intention to decelerate the vehicle in a car-following situation. In the present study, a field observation of a car driving and an experiment were conducted. In the field observation, the data were collected for analyzing a driver's maneuvering of the accelerator and brake pedals in order to design a system that can detect the driver's intention to deceleration. The method based on the covering brake pedal found to be highly reliable. In the experiment, an investigation using an experimental vehicle and a test course was conducted to evaluate the influence of the proposed system on the driver behavior. The experimental results showed that the system was effective in improving the driver's accelerator release time (ART) and the brake onset time (BOT).

Keywords: Safety, Intelligent vehicle, Driver support, Driver behavior.

1 Introduction

Recently, technologies for preventing road traffic crashes have been actively developed worldwide. Rear-end collisions are one of the most common type of accidents. Today's intelligent and autonomous automobiles, are equipped with many sensors and computers, and they can sense and analyze situations, decide what must be done, and implement control actions. Examples of such systems include the Forward Collision Warning System (FCWS) [1-2] and Collision Avoidance System (CAS) [3]. FCWS provides warnings to encourage a driver to take appropriate actions to avoid a crash, and is to enhance a driver's situation awareness [4]. If the driver does not take appropriate action after the warning is issued, CAS performs a control intervention on behalf of a human, and is to trade a control authority in emergency. These Advanced Driver-Assistance System (ADAS), which is installed in a vehicle, adaptively interact with and assist the driver in a situation-adaptive manner [5].

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S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 548–557, 2013.

Furthermore, studies have also focused on methods to improve the interaction between the vehicles in car-following situations. For example, the Emergency Stop Signal (ESS) [6] enhances the situation awareness of a following driver about the forward vehicle's behavior. Saffarian and Happee [7] proposed a car-following assisting system named as Rear Window Notification Display (RWND) for effective interaction between vehicles under normal driving situations. Its interface quantifies the acceleration and time-headway (THW) of the instrumented forward vehicle. These ADAS interacts between the vehicles and helps redirect the driver's visual glance and pays the attention to forward roadway. Saito et al. [8] have proposed a deceleration intention indicating system, which indicates a driver's intention to decelerate the vehicle in advance. This system was developed for effective interaction between vehicles in car-following situations. Where RWND indicates the acceleration and THW based on the vehicle's data such as the acceleration, the proposed system indicates the same by judging the driver's intention to decelerate based on his/her actual maneuver. This system has been developed to enhance a driver's situation awareness.

This paper discusses a way to detect the driver's intention to decelerate. In the present study, a field observation of a car driving and an experiment were conducted. In the field observation, the driving performance data were collected for analyzing the state of his/her maneuver of the accelerator and brake pedals in order to design a system that can detect the driver's intention to decelerate. In the experiment, an investigation using an experimental vehicle on a test course was conducted to evaluate the influence of the deceleration intention indicating system on the driver behavior.

2 System Concept

In situations where a vehicle is following another, such as in traffic, the deceleration intention indicating system indicates the driver's intention to decelerate of the forward vehicle before the braking maneuver is actually initiated. The system aims to improve the following driver's predictions and expectations regarding the forward vehicle's behavior, and to reduce the risk of a rear-end collision by impelling the following driver to decelerate early. The system consists of an auxiliary stop lamp, which is installed on the rear window of the forward vehicle. According to the domestic preservation standard in Japan, a stop lamp is obliged to operate by a consecutive lighting of a red light. A following driver reacts to the lighting of the stop lamp reflectively based on his/her experiences and educations. The proposed system serves as an auxiliary stop lamp, and its operation is indicated by a consecutive lighting of a yellow light. The lighting of a stop lamp generally indicates braking, but the auxiliary stop lamp in this system indicates the driver's intention to decelerate.

Judgment on Presence or Absence of Driver's Deceleration Intention. In this study, we have attempted to judge whether the driver's intention to decelerate based on his/her actual maneuvering of the brake and accelerator pedals. The following situations were considered.

1. Accelerator off (accelerator output is 0%).
2. Presence or absence of the driver's foot above the accelerator pedal.
3. Presence or absence of the driver's foot above the brake pedal.

These situations are useful to judge the driver's intention to decelerate. The system can determine that a certain behavior indicates the driver's intention to decelerate because the vehicle slows down with the driver's maneuver. However, if the system were to assume that a driver hits brake only when he/she intends to decelerate, the judgment will be not reliable enough. For example, when a driver implements the accelerator off, he/she may implement so for maintaining speed. In this case, the brake maneuver is not implemented. This is because the information may be indicated before the driver decides about implementing a brake maneuver or because a driver may change the decision-making based on traffic conditions after having finished decision-making about the brake maneuver. First, field observations of the experimental vehicle being driven were performed to analyze the driver's maneuvering of the accelerator and brake pedals.

3 Data Collection

3.1 Method

Apparatus. The experimental vehicle (Toyota Progress 2,500cc) used in the field observation can measure the state of maneuver of the accelerator and brake pedals.

Participants and Driving Task. Two drivers (two male) aged 26 and 45 have participated. The participants are researchers from the National Institute of Advanced Industrial Science and Technology (AIST). The participants hold a valid driver's license and drive daily. Their task was to drive safely on public-roads in Tsukuba-city. The participants drove a specified course freely (length: approximately 13km).

Measures. The driving data collected in the study were the speed (km/h), acceleration (G), inter-vehicle distance (m) (measured with the laser sensor), GPS-time (s), displacement of the accelerator and brake pedals, and presence or absence of the driver's foot above the accelerator or brake pedals (ON/OFF). The frequency of data collection was 30Hz. The "Cover accelerator pedal" (Cover AP) refers to the presence or absence of the driver's foot above the accelerator pedal and "Cover brake pedal" (Cover BP) refers to the presence or absence of the driver's foot above the brake pedal. The experimental vehicle was equipped with the electronic photo sensors in order to detect the presence or absence of the driver's foot above these pedals (Fig.1).

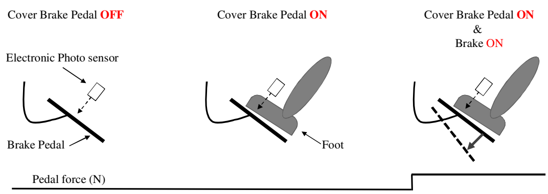

Fig. 1. Specific of Cover BP ON/OFF (Cover AP is detected in a similar manner.)

3.2 Results and Discussions

An analysis of the state of maneuver of the accelerator and brake pedals was performed on the following items. The calculated item shows the time to indicate the driver's intention to decelerate and the credibility of the system's indication.

- Time to implement the brake maneuver from implementing the "Accelerator OFF", "Cover AP OFF", and "Cover BP ON" maneuver.
- Rate of actual implementing the brake maneuver after implementing the "Accelerator OFF", "Cover AP OFF", and "Cover BP ON" maneuver.

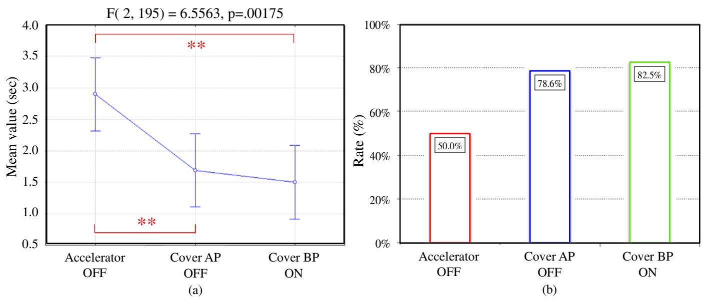

Fig. 2. (a): Time to implement the brake maneuver from implementing each behavior, (b): Rate of implementing the brake maneuver after implementing each behavior (**p<0.01, *p<0.05)

As seen in Fig.2 (a), the time to implement the brake maneuver from implementing the "Accelerator OFF" was the longest with 2.9 s as the mean value, and the time to implement the brake maneuver from implementing the "Cover BP ON" was the shortest with 1.5 s as the mean value. On the other hand, as seen in Fig.2 (b), the rate of actual implementing the brake maneuver after implementing the "Accelerator OFF" was the lowest (50.0 %), and the rate of actual implementing the brake maneuver after implementing the "Cover BP ON" was the highest (82.5 %). Additionally, as a result of having performed analysis of variance (ANOVA) on the time to implement the brake maneuver from implementing each behavior, the main effect was highly statistically significant ($F(2, 195)=6.5563, p<0.01$). According to Tukey's HSD test, significant differences were found between "Accelerator OFF" and "Cover AP OFF", and between "Accelerator OFF" and "Cover BP ON".

Summarizing these results, when the system judges the driver's intention to decelerate by detecting the "Accelerator OFF", the time when the information is indicated before the braking maneuver is actually initiated was the longest, but the rate of actual implementing the brake maneuver after implementing the "Accelerator OFF" was the lowest. In other words, the credibility of the information indicated by the system when it judges the driver's intention to decelerate was the lowest. When the system judges the driver's intention to deceleration by detecting the "Cover AP OFF" or "Cover BP ON", no significant differences were found in the time when the information is indicated before the braking maneuver is actually initiated. The credibility of the information indicated by the system was higher when it judges the driver's intention to decelerate based on "Cover BP ON" than when it judges the same based on "Cover AP OFF". From these results, when the system detects the driver's brake maneuver intention based on each behavior listed above, the judgment was not reliable enough. In the present study, we have designed a system that bases its judgment of the driver's intention to deceleration on Cover BP in order to make the judgment more reliable. That is, the system judges that the driver intends to decelerate when his/her foot is above the brake pedal.

The time taken to indicate the driver's intention to decelerate was less than 2 s occupy most in approximately 70% of the case. The most frequent value was less than 0.5 s, and it occurred in 37.9% of the case. The time taken by the system to convey the driver's intention to decelerate was between 0.5 and 1 s, 1.0 and 1.5 s, and 1.5 and 2.0 s in 22.7%, 9.1%, and 9.1% of the cases, respectively. The time taken depends on the traffic conditions and the driving attitude of the driver. Assuming the situation where the auxiliary stop lamp turns on for approximately 1.0 s before the braking maneuver is actually initiated, improving the following driver's predictions and expectations regarding the forward vehicle's behavior is needed.

4 Experiment

The purpose of the experiment is to clarify the following points: (1) effect of the system, and (2) influence of the system on the driver behavior. The following working hypothesis is made: the system improves the following driver's predictions and expectations by indicating the driver's intention to decelerate in the forward vehicle. Therefore, the following driver can prepare to take an appropriate action for the deceleration in advance, and the system can impel the driver to decelerate early.

4.1 Apparatus

By using two experimental vehicles, we recorded the data for the same items as in the field observation. In addition, the measurement items of two vehicles were synchronized by GPS time (Fig.3). Further, the forward vehicle's acceleration and deceleration were controlled the automatically in order to ensure the reproducibility. Therefore, the forward vehicle had automated speed control (Mazda Millenia 2,500cc), and the following vehicle (Toyota Progress 2,500cc) was the experimental vehicle used to measure the driver behavior.

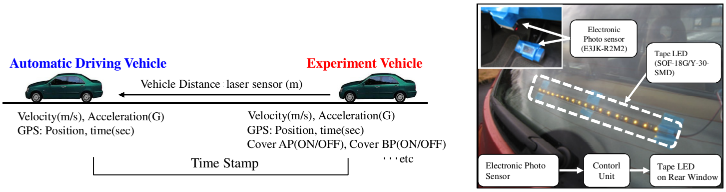

Fig. 3. Experimental vehicle and set-up

The system was set up with the auxiliary stop lamp on the rear window of the automated vehicle (Fig.3). It was indicated via a Tape LED (SOF-18G/Y-30-SMD), and a reflection plate (E3JK-R2M2) was installed on the brake pedal. When the electronic photo sensor detects that the driver has put their foot above the reflector plate, the auxiliary stop lamp is turned on. In this experiment, it was indicated by the program automatically in order to ensure the reproducibility. The indicating time was set 1.0 and 1.5 s. It was designed based on the results of the field observation.

4.2 The Participants, Driving Task, and Procedure

Four drivers (four male) aged 23 - 45 have participated in the experiment. The participants are researchers from AIST. The participants hold a valid driver's license and drive daily. A driving task was to drive safely in the cruising lane in a car-following situation. The experiment was performed on the test track of AIST. The experimental course is an oval course (3.2km). The forward vehicle kept driving on the same lane. Other vehicles were not allowed to enter the test course. The speed profile of the automated vehicle (forward vehicle) is shown in Fig.4. It was designed with reference to 10・15 and JC08 mode, which is used to evaluate fuel efficiency in Japan.

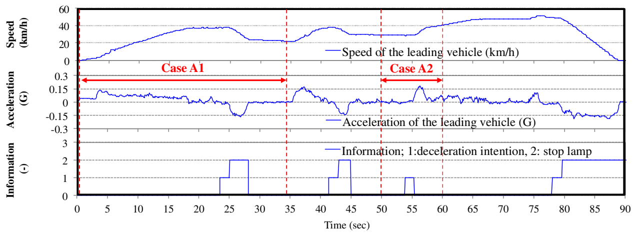

Fig. 4. Driving profile of automated vehicle

This experiment consisted of four sessions. The 1st session was a short introduction session of approximately 6.0 min. In the 2nd session, the participants drove without the proposed system. It was performed repeatedly four times. In the 3rd session, the participants drove at the support condition as described in the next subsection. It was also performed repeatedly four times. In the 4th session, the participants drove again without the proposed system (baseline condition). It was also performed repeatedly four times. Before the 1st session, the participants were instructed about the operation, test procedure and driving task. The systems' interface was also explained.

4.3 Independent Variable

Driving condition was the within subject variable. Two conditions were distinguished as follows:

1. Support condition: The system indicates the driver's intention to decelerate of the forward vehicle before the braking maneuver is actually initiated.
2. Baseline condition: No support function is available.

4.4 Dependent Variable

The data collected were the speed (km/h), acceleration (G), inter-vehicle distance (m), GPS-time (s), displacement of the accelerator and brake pedals (mm), and Cover AP/BP (ON/OFF). Additionally, the following items were calculated:

- The relative speed between the vehicles.
- The Time-Headway between the vehicles (THW).
- The inverse of TTC between the vehicles (iTTC).
- Time to release the accelerator from forward vehicle initiated slowdown (ART).
- Time to implement the brake from forward vehicle initiated slowdown (BOT).
- Time to implement the brake maneuver from Cover BP ON (MT).
- Time to implement to accelerate from forward vehicle initiate to accelerate (AOT).

4.5 Scenario

The scenario in the experiment consisted of two events, named A1 and A2 (Fig.5).

- A1: Vehicle B maintains as speed of 40km/h for 6 s. After that, vehicle B slows down to 20km/h at 0.15G. Then, the driver's intention to decelerate is indicated for 1.5 s before vehicle B slows down.
- A2: Vehicle B maintains as speed of 30km/h for 10 s. Then, the driver's intention to decelerate is indicated for 1.0 s. After that, vehicle B accelerates without slowing down.

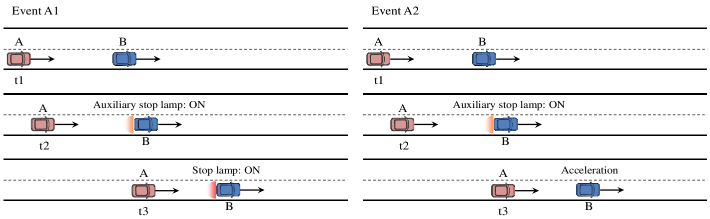

Fig. 5. Event A1 and A2

4.6 Results

The experimental results of session 3 (support condition) were compared with those of session 4 (baseline condition). The data of one participant (participant no.4) was excluded in the analysis data, because how to get inter-vehicle distance changed and it was difficult to compare between conditions. Furthermore, when there was an unintended acceleration of the automated vehicle, the data was excluded. In this experiment, there was once unintended acceleration.

Event A1. Table 1 shows the driving performance metrics. In this analysis, we performed a t-test on each value. Several significant differences were found, and these were found for the minimum of relative speed ($p<0.05$) and the maximum of acceleration ($p<0.01$). A marginally significant difference was found in iTTC ($p<0.1$). These results showed that the relative speed and the maximum acceleration were suppressed by indicating the driver's intention to decelerate.

The results of the t-test on ART and BOT are shown in Figs.6 and 7. Significant differences were found in the mean of ART ($p<0.01$) and BOT ($p<0.05$). ART was -0.68 (SD: 0.47) s at the mean value in the support condition. As a result of the driver having prepared early for the deceleration, BOT was 0.23 (SD: 0.82) s at the mean value in the support condition, and it improved to 0.63 s at the mean value compared with the baseline condition. ART and BOT were improved by the system, and the slowdown behavior of the following driver was quick. The results of the t-test on MT are shown in Fig.8. Significant differences was found in MT ($p<0.05$). MT was 0.61 (SD: 0.44) s at the mean value in the support condition, and it was 0.23 (SD: 0.11) s at the mean value in the baseline condition. Therefore, the results showed that the following driver could prepare to take appropriate action for the deceleration in advance.

Table 1. Driving performance, mean (SD)

	Min Relative speed (m/s)	Max Acceleration (G)	Max Displacement of brake pedal (mm)	Min THW (sec)	Max TTC^{-1} (1/sec)
Without-system	-2.31(0.376)	-0.25(0.036)	33.74(3.006)	1.365(0.256)	0.175(0.028)
With-system	-1.66(0.638)	-0.18(0.037)	31.92(2.185)	1.355(0.298)	0.146(0.037)
p < (Without-system vs With-system)	**0.01214**	**0.00026**	0.104	0.96985	0.0534

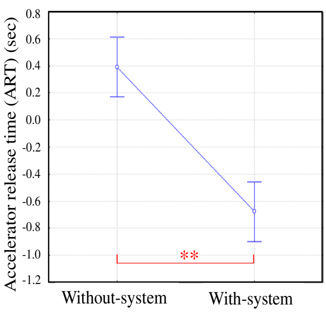

Fig. 6. ART

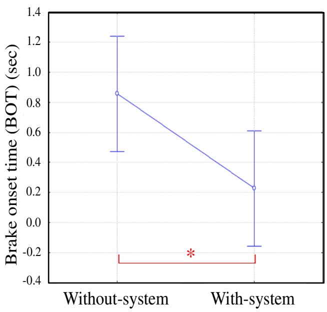

Fig. 7. BOT (**p<0.01, *p<0.05)

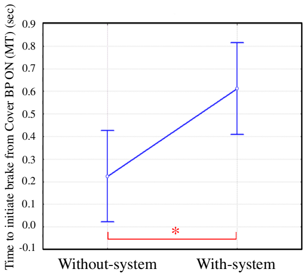

Fig. 8. MT

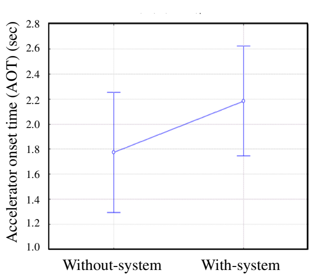

Fig. 9. AOT (**p<0.01, *p<0.05)

Event A2. The results of the t-test on AOT are shown in Fig.9. No significant differences were found in the mean value of AOT. If the forward vehicle initiates to accelerate, the following driver's acceleration maneuver may be late, because the system does not provide any information about the forward vehicle's acceleration. If the delay is large, there is a possibility that the traffic flow will be affected. The result claims that the impact on the traffic flow by the system is small in case of event A2.

4.7 Discussions

The system indicated the driver's intention to decelerate before the braking maneuver is actually initiated. This gave the following driver predictions and expectations regarding the forward vehicles' behavior in the near future. The system offers a support in order to improve the following driver's predictions and expectations regarding the traffic conditions that may occur in the next few seconds as well as those regarding other road users' actions. In other words, the system enhances the situation awareness of a following driver. Situation awareness can be classified into three levels [4]: Level1: perception of elements in the environment, Level2: comprehension of current situation, and Level3: projection of future status. The system helps the driver to attain situation awareness levels 1, 2, and 3. In event A1, the system gave an opportunity to utilize the driver's intention to decelerate as a means to improve the following driver's prediction of the vehicle's upcoming behavior. These predictions can be used to adjust the timing of actions and to implement the actions. From the result of ART in Fig.6, the following driver released the accelerator pedal before the brake maneuver of the forward vehicle is actually initiated. The results showed that the system was effective in improving ART and BOT of the following driver. In addition, the system was effective in providing some safety margins because the following driver could prepare to take an appropriate action for the deceleration in advance (Fig.8). From the above, the driver, assisted by the proposed system, could prepare for the deceleration in advance by recognizing the driver's intention to decelerate and predicting the vehicle's upcoming behavior. Enke [9] showed that an improvement of the driving behavior has the same effect as a maneuver to avoid a crash, which is started a few tenths of a second earlier. It estimated that it could evade the half by an improvement of 0.5 s for the correspondence of driver in the rear-end collisions. Therefore, the effect of the mitigation or avoidance of rear-end collisions is needed by using the deceleration intention indicating system.

5 Concluding Remarks

This paper discussed a way to detect the driver's intention to decelerate in a car-following situation. In the present study, a field observation and experiment were conducted. In the field observation, the driving performance data were collected for analyzing the state of the following driver's maneuver of the accelerator and brake pedals in order to design a system to detect the driver's intention to decelerate. The method based on the covering brake pedal was shown to be most reliable in judging the driver's intention to decelerate of the forward vehicle. In the experiment, the experimental results showed that the system was effective in improving the following driver's ART and BOT, and it provided some safety margins because the following driver could prepare to take an appropriate action for the deceleration of the forward vehicle in advance.

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Human Behavior of Prioritizing Right-Turning Vehicles and Traffic Flow at Intersections

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Abstract. This study evaluates the effect of prioritizing right-turning vehicles in traffic flow not only at an artificial intersection but also at an existing corridor equipped with several intersections. The traffic simulator used in this study quantifies the effect of prioritizing a right-turning vehicle on traffic efficiency, safety, and the environment of an intersection. The ratio of prioritizing a right-turning vehicle is given as stochastic probability density functions. Numerical analysis showed that low traffic demand and low probability of prioritizing a right-turning vehicle brought significant improvement to traffic efficiency, safety and the environment. The effect was as significant as installing a general right-turn pocket and its special signal phase. It was concluded that humans have potential to improve this efficiency as significant as that of when a right-turn pocket is installed, which is costly and time-consuming.

Keywords: Driver Assist, Man-Machine System, Human Interface, Active Safety, Motivation, Right-turn Prioritizing.

1 Introduction

Vehicles waiting to complete a right turn often block the vehicles upstream of the intersection and yield a long queue. The traffic congestion due to such blockage is usually avoided by preparing a right-turn pocket (RTP) and/or a special signal phase for the right-turning vehicles as is a conventional method in civil or traffic engineering. Due to the restricted use of land in Japan, many intersections that are prone to such congestion have no available space to prepare a special lane for right-turning vehicles, even at intersections along national highways.

The authors have focused on human factor and the motivation of the drivers of the on-coming through traffic to give a “right-of-way” to a right-turning vehicle in order to alleviate traffic congestion around intersections. Although a right-turning vehicle has lower priority when passing through an intersection, according to Japanese traffic

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S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 558–567, 2013.

regulations, this research focuses on prioritizing right-turning vehicles rather than the on-coming through traffic.

Rather than investigating the human-machine interface (HMI) in detail, we applied a traffic simulation and evaluated the effect of right-turn prioritization on traffic flow at a signalized intersection. Our previous work [1][2] concluded that the prioritization is effective for traffic efficiency, safety and the environment. However, the prioritization was only tested in a virtual two-way corridor of an actual highway that utilized completely artificial traffic data of a single intersection. It still remains unclear whether this is effective when real data are used and the traffic of multiple intersections is included.

The research of the current study applies a traffic simulation to a real arterial corridor that is equipped with several signalized intersections and evaluates the effect of prioritizing a right-turning vehicle in traffic flow around the intersections. For comparison, a sensitivity analysis using artificial data based on our previous work [2] is also given. It should be noted that human factor and the human-machine interface are regarded as future work as the effect was not entirely confirmed.

2 Sensitivity Analysis Using Artificial Data

2.1 Study Area

The study area is a typical four-leg signalized intersection where no through traffic can pass a right-turning vehicle waiting to make a right turn, as depicted in Fig. 1.

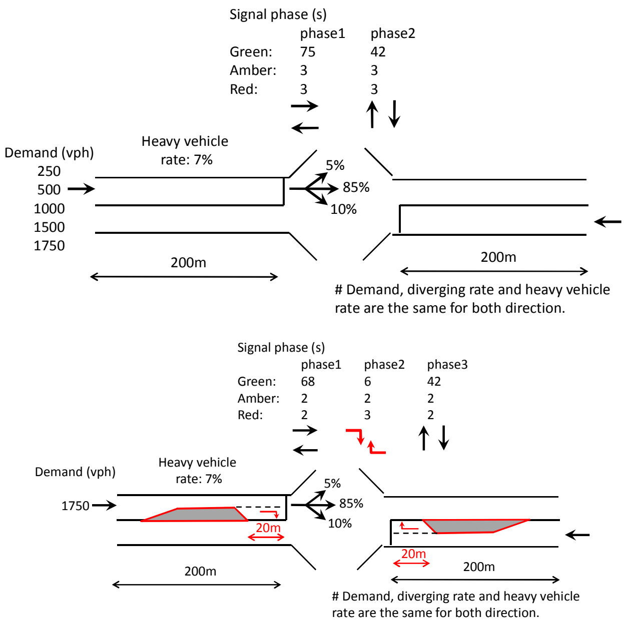

Fig. 1. Study area (upper: without right-turn pocket; lower: with right-turn pocket)

In addition, a 20 m RTP and its special signal phase are prepared to compare the efficiency of the right-turning vehicle prioritization.

2.2 Simulation Input

Traffic Demand. Traffic demand is set to 250, 500, 1000, 1500 and 1750 vehicles per hour (vph) for both inbound and outbound traffic.

Diverging Rate. The intersection is set at 5% left-turning traffic, 10% right-turning traffic and 85% through traffic for both inbound and outbound lanes. Right-turning is set at a slightly higher rate in order to simulate significant congestion at the intersection.

Gap Acceptance. The minimum time gap for a vehicle to complete a right-turn is denoted as gap acceptance and is set to 6 s.

Heavy Vehicle Rate. The heavy vehicle rate is set to a constant value of 7% for both directions.

Signal Phase. For the case in which no RTP is installed at the intersection, the period of a green signal light is set at 75 s and the period of the amber and red signal lights is set to 3 s to regulate traffic using a pre-timed control with a 129 s cycle length. For the case in which a RTP is installed, the cycle length remains unchanged, but 6 s and 2 s are set for the right-turn green and amber phases, respectively.

Car-Following Model. The mathematical model that simulates a longitudinal car-following is described as follows:

$$\ddot{x}(t+T) = a\left(\frac{\Delta v}{\ell} \cdot v^{\alpha}\right) + b\left(\sqrt[\delta]{\beta \cdot v^{\gamma}} - \frac{v}{\ell}\right) + c\left(\frac{R}{1+m \cdot \exp(n \cdot \ell)}\right) + d \tag{1}$$

where, t is the time step, T is reaction time, Δv is relative speed, v is the speed of the follower, and ℓ is headway distance. The other variables are all model parameters to be identified by a regression analysis using observed car-following data.

The proposed car-following model has been previously validated to show that it is capable of describing the maneuvers of typical Japanese drivers [3].

Simulation Parameters. A traffic simulator that utilizes the car-following model simulates the acceleration rate, speed and position of each vehicle every 0.1 s for a duration of 3600 s. It also outputs the average travel time per vehicle, time gap of right-turning vehicles and the total CO2 emission at the end of the simulation. Ten different random seeds are used for each simulation trial to identify the general traffic phenomena during the various traffic patterns. Note that the traffic simulator has been previously validated using the manual published by the Japan Society of Traffic Engineers (JSTE) [4].

2.3 Modeling Human Behavior to Prioritize Right-Turning Vehicles

Behavior of Through Vehicles. When a vehicle of through traffic identifies an up-coming right-turning vehicle, it decelerates naturally as if the signal turns to amber or red. To model this maneuver, ℓ in Equation (1) is set to the distance between the vehicle and the stop line, and the speed of a preceding vehicle is assumed to be 0 m/s. It is expected that such a natural deceleration of an on-coming vehicle yields a longer time gap and thus a more likely chance of completing a turn for a right-turning vehicle.

Probability of Prioritizing Right-Turn Vehicles. Human behavior of whether an on-coming vehicle gives a right-of-way to a right-turning vehicle is modeled by 10 varying probability density functions (PDFs) as illustrated in Fig. 2. It is assumed that the probability increases when the queue length caused by the right-turning vehicle is elongated. For instance, when comparing patterns 2 and 8 (pt. 2 and pt. 8) in Table 1, the driver of pt. 8 has a higher probability of giving a right-of-way to a right-turning vehicle than the driver of pt. 2. The PDFs and their parameters are artificially defined in Equation (2) and listed in Table 1.

$$y = \begin{cases} \exp\left(\frac{w}{p_a}\right) \Big/ p_b \\ p_c \\ p_d \cdot x \\ \dfrac{1}{1 + p_e \exp\left(-p_f \cdot w\right)} \end{cases} \tag{2}$$

where, w is the number of vehicles blocked by a right-turning vehicle and y is the probability of prioritizing the right-turning vehicle.

Table 1. Parameters for prioritizing a right-turning vehicle

pattern	P_a	P_b	P_c	P_d	P_e	P_f
1	-	-	0	-	-	-
2	2	1100	-	-	-	-
3	3	82	-	-	-	-
4	5	13	-	-	-	-
5	-	-	0.5	-	-	-
6	-	-	-	0.083	-	-
7	-	-	-	-	40	0.7
8	-	-	-	-	30	0.9
9	-	-	-	-	50	1.4
10	-	-	1	-	-	-

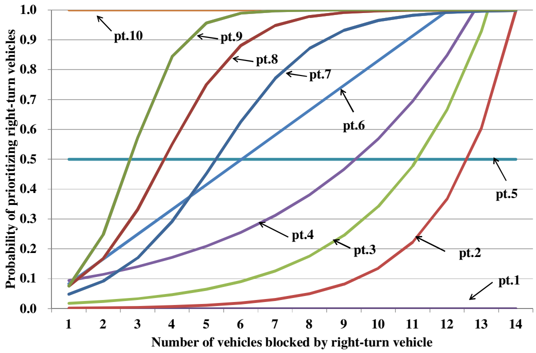

Fig. 2. Probability density functions for prioritizing right-turning vehicles

2.4 Measures of Effectiveness (MOE)

Efficiency. The efficiency as a Measure of Effectiveness (MOE) is defined as the average travel time for a nominal vehicle to traverse the road link from the upstream end to the stop line, as defined in Equation (3). When the efficiency is obstructed, the travel time increases.

$$\overline{ttm} = \sum_{i=1}^{N_t} ttm_i \Big/ N_t \tag{3}$$

where, $\overline{ttm}$ is the average travel time, ttm_i is a travel time of vehicle i, and N_t is the total number of vehicles passing the stop line.

Safety. Safety is measured as the average headway time between a right-turning vehicle and the on-coming through traffic when completing a right-turn maneuver. A long headway time indicates a safer probability of a right turn. The average time headway is given by:

$$\overline{thw} = \sum_{i=1}^{N_s} thw_i \Big/ N_s \tag{4}$$

where, $\overline{thw}$ is the average time headway, N_s is the number of vehicles that completed a right-turn, and thw_i is the time headway computed by:

$$thw_i = \frac{x_r^i + x_d^i + x_c}{v_d^i} \tag{5}$$

Here, x_r^i and x_d^i are the distances between the stop line and right-turning vehicles and on-coming through vehicles, respectively. x_c is the size of the intersection and is set to 15 m for general cases. v_d^i is the velocity of an on-coming vehicle.

Environment. The MOE for the environment is defined as the amount CO2 emission. The traffic simulator used here calculates the acceleration rate, speed and the driving force of each vehicle. Then, the CO2 emission map provided by the Japan Petroleum Energy Center (JPEC) [5] indicates the emission from the driving force and vehicle speed as shown in Fig. 3. For instance, where 1500 N of driving force and 50 km/h in speed intersect, an estimated emission of 7.02 g/s can be obtained.

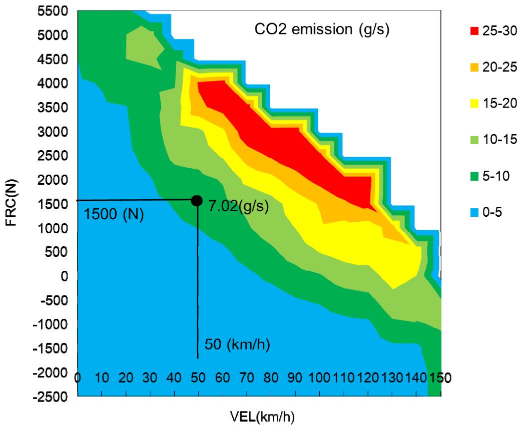

Fig. 3. CO2 emission map [5]

2.5 Estimation Results

Fig. 4 compares traffic efficiency among the 10 prioritizing patterns for inbound and outbound traffic. It should be noted that the case in which the RTP was installed is indicated on the far-right horizontal axis. It is found that:

- The average travel time significantly decreased as the through traffic prioritized the right-turning vehicle more.
- Significantly high efficiency is observed even with small traffic demand, such as in the case of 500 vph.
- No effect was observed for 250 vph since the lower traffic demand did not generate a stopped right-turning vehicle that yielded severe congestion.
- Even at low right-turn prioritizations, such as in pts. 2 to 4, efficiency increased.
- Installing the RTP is similar to the prioritizing pts. 9 or 10. This implies that human behavior has potential to improve efficiency as much as installing a RTP, which is costly and time-consuming.

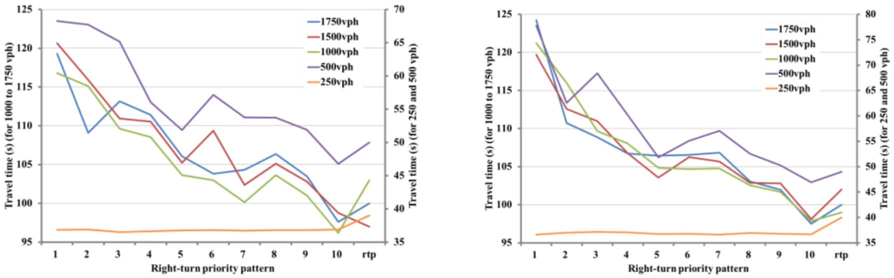

Fig. 4. Travel time comparison among the 10 patterns of prioritization (upper: inbound traffic; lower: outbound traffic)

The average headway time, as a MOE of safety, is also increased as more vehicles prioritize the right-turning vehicle, as depicted in Fig. 5. If each driver gives a right-of-way to the right-turning vehicle, approximately 1 s is additionally provided to the right-turning vehicle when compared to no prioritization case. Although not yet confirmed, this may be enough time to decrease the risk of collision.

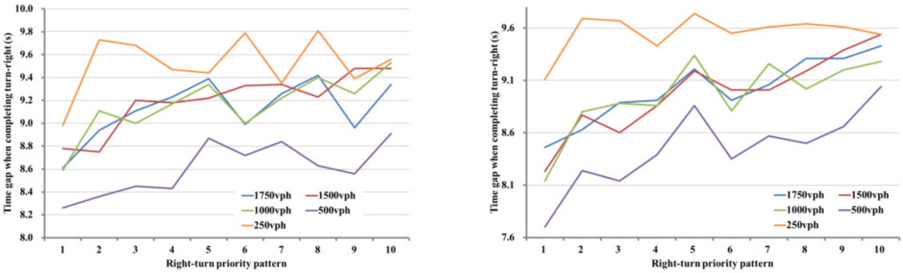

Fig. 5. Comparison of average headway time when completing a right turn (upper: inbound traffic; lower: outbound traffic)

Fig. 6 illustrates that not only the efficiency and safety but also the environment is improved by the right-turn prioritization. The high efficiency of traffic resulted in decreasing the frequency of low-speed driving in which more CO2 is emitted.

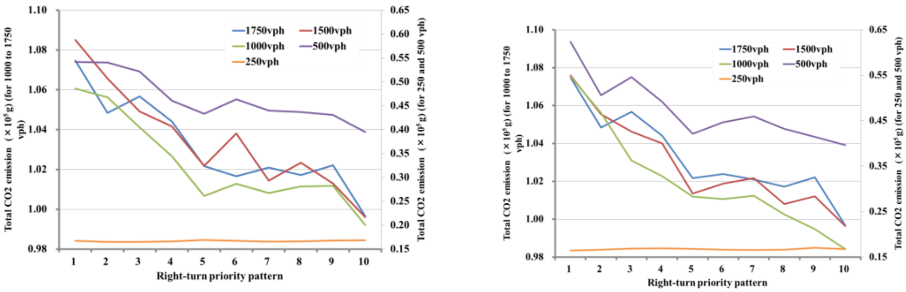

Fig. 6. Comparison of CO2 emission (upper: inbound traffic; lower: outbound traffic)

3 Evaluation of Real Corridor Use with Real Traffic Data

The numerical analysis demonstrated above shows that the right-turn prioritization is effective for traffic efficiency, safety and environment. To investigate if it is also valid for a real world scenario, the proposed analysis is extended and applied to an existing arterial corridor in Japan.

3.1 Data Collection

For this evaluation, the study area is located in Yachiyo City, Chiba Prefecture, Japan, where a two-way national highway, Highway 296, is prone to severe traffic jams caused by the blockage of right-turning vehicles, which is especially severe on weekends. As illustrated in Fig. 7, both the inbound and outbound corridors connected to the three intersections have neither a RTP nor a special signal for right turning.

Actual data was collected through a field survey on Saturday, November 10, 2012, from 12:30 to 14:00 JST. Due to the low number of surveyors and video cameras, traffic data in each direction and intersection were each collected in approximately 10 to 15 min intervals.

3.2 Simulation Input

The input parameters for the traffic simulation are also given in Fig. 7. Traffic demand is set at 648 vph for westbound and 888 vph for eastbound traffic. The diverging rate for right-turning vehicles is 13 to 14%, which is higher than the assumptions made in the previous analysis in Chapter 2. The modeling of human behavior for prioritizing right-turning vehicles and the MOE remain unchanged.

The numerical analysis here tries to investigate whether the similar effect will be observed by the simulation with actual data.

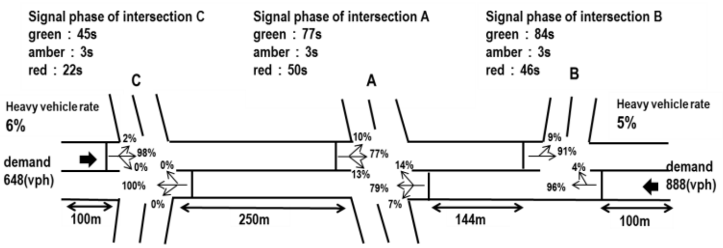

Fig. 7. Study area and Input for traffic simulation

3.3 Estimation Results

Figs. 8, 9, and 10 illustrate the results of average travel time, time gap and CO2 emission for west and east bound traffic. These figures suggest that the traffic efficiency, safety and environment are all improved when prioritizing right-turning vehicles, which is similar to the analysis using artificial traffic data.

Travel time and CO2 emission reductions are significant, especially for eastbound traffic in which right-turn prioritizing reaches a maximum of 20% in improvement. The time gap also increased by a maximum of 1 s, which may be enough time for a vehicle to make a right turn with a lower risk of collision.

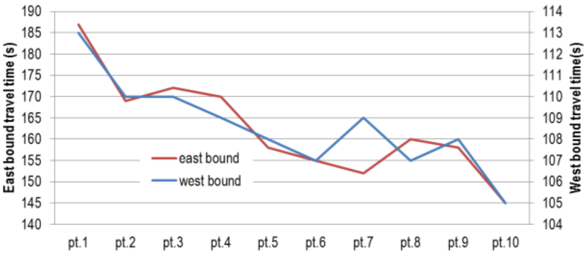

Fig. 8. Travel time estimation

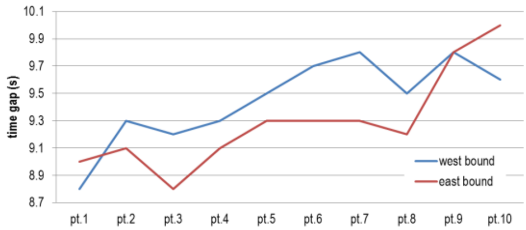

Fig. 9. Time gap estimation

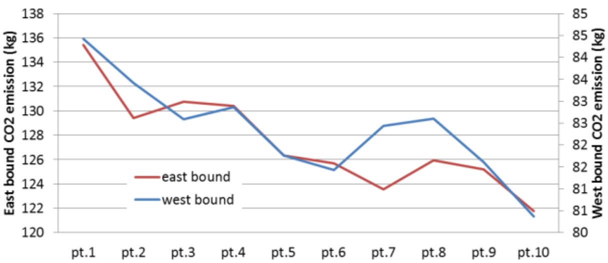

Fig. 10. Estimated CO2 emission

4 Conclusion

This research focused on the human behavior to prioritize right-turning vehicles rather than the through traffic at a signalized intersection without a RTP and/or special signal phase. A numerical analysis using a traffic simulator showed that giving a right-of-way to a right-turning vehicle is effective in alleviating traffic congestion, reducing the risk of collision when completing a right-turn and decreasing CO2 emission on a highway corridor. It is confirmed that this result is valid not only when using a virtual corridor with artificial data but also at an existing national highway in Japan. Humans have potential to improve this efficiency as much as that provided when a RTP is installed, which is costly and time-consuming.

Further studies are needed to design the HMI that encourages through traffic drivers to prioritize right-turning vehicles. What information is effective, how and when the information is given to the drivers are also important factors to design the HMI. Analyses and experiments are also required in order to design the HMI using a driving simulator integrated with a traffic simulator.

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Acceptable System Error of Collision Avoidance System Based on the Integrated Error of Driver and System

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Abstract. This study uses collision-prevention support information at a blind intersection as an example to discuss a methodology for estimating the collision mitigation ratio when the collision avoidance information is used by a driver. It also discusses the acceptable delay time for information presentation regarding a crossing vehicle at a blind intersection. First, driver performance in terms of braking timing and deceleration operation for collision avoidance was analyzed in a driving simulator when the onset timing of the information to notify the driver about a crossing vehicle was changed. Next, a driver model was constructed that simulated a braking operation when a crossing vehicle appeared at a blind intersection where there were no traffic signals. Through Monte Carlo simulations using this driver model, an estimation was made of the frequency of collisions to vehicles crossing the blind intersection. In addition to this estimation, the acceptable delay time for presenting the information was estimated. One of the results indicates that the delay time should be less than 2 s. This means the information should be presented to the driver when the time to collision (TTC) is longer than 3 s to mitigate the probability of collision.

Keywords: Driver Behaviour, Intersection, Face-to-Face Collision, Information for Collision Avoidance, Collision Mitigation, Sensor Reliability, Driver Model.

1 Motivation of the Study

This paper proposes a methodology to clarify the acceptable level of the sensors' reliability to reduce collisions at intersections based on the concept of 'integrated error of driver and systems' that authors had reported in previous research [1]-[3]. In that study, an information presentation system was proposed that notified drivers about vehicles crossing blind intersections. This system is used as an example for the discussion and the methodology is used to clarify the acceptable reliability level for the information presentation. This study includes a discussion of this acceptable reliability level, which means the acceptable delay time for presenting the information about crossing vehicles to the driver. First, we investigated the collision-avoidance

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 568–576, 2013.

behavior of drivers at traffic intersections, testing 20 drivers in a driving simulator. We constructed a database that captured the driving behavior of the subjects as they decelerated to avoid collisions at the simulated intersection in two different situations. In one situation, the information about the vehicle as it approached the intersection was presented to the driver without any delay time. In the other situation, the information was presented with a delay time. The change in driver behavior when the timing of information presentation was delayed was investigated. Two different timing delays for presenting the information to the driver were used during the experiment. Next, using the database, a driver model that simulated the collision avoidance at the intersection was constructed. The Monte Carlo method was applied for the simulation, and then using this driver model, the collision-avoidance behavior of the drivers was investigated, to estimate not only the effectiveness of the information presentation but also the acceptable delay time of the information presentation. These investigations were carried out, not only during the normal operation of the system but also during delayed operations in which the system presented the information to the driver with delayed timing. Using a methodology that estimates the relationship between the delay time of the information presentation and the effectiveness of the system, the acceptable delay time of the information presentation was clarified quantitatively in this study.

2 Experimental Method

2.1 Experiment Scenario

Using accident statistical data [4][5] and the results from an investigation using an event data recorder, which analyzed the characteristics of traffic accidents at intersections, we determined the speed of cars travelling on a priority road and that of the cars travelling on a non-priority road. In the visual database of the simulator, we constructed a blind intersection with narrow roads which is typical intersection in the residential area of Japan. We constructed a priority road where the travelling velocity is 40 km/h, and a non-priority road where the travelling velocity is 20 km/h. These two roads crossed at an intersection. The width of the road and the position of the obstacles blocking the views from the traffic lanes were specified to match the dimensions of a specific intersection in a metropolitan area of Japan where collisions actually occurred. Each test subject drove a simulated vehicle while it travelled a priority road. A simulation of another vehicle was made to advance into the intersection from the crossing road without deceleration. For each test, the existence of the test subject's vehicle and the direction of this oncoming vehicle advancing into the traffic intersection were set up in a random order. When the time to collision (TTC) became lesser than 1.6 s, the subject driver could visually detect the oncoming vehicle. This condition was specified, based on the database of specific traffic accidents in the metropolitan area. In other words, the buildings beside the intersection were placed such that the driver could not view the oncoming vehicle until 1.6 s before the collision.

When considering the mental condition of the driver when the collision occurred, it is assumed that something was mentally distracting the driver. In this experimental study, a mental arithmetic calculation was presented to the drivers while they drove a simulated vehicle, to simulate this mental distraction. Specifically, a numerical figure was presented to the driver every 3 s and the driver was asked to add this to the previous answer and respond with the first digit as the answer.

2.2 Collision Avoidance Information

In the experiments, when the subject's vehicle was approaching the intersection and the crossing vehicle was also approaching the same intersection, the visual and voice information about the vehicle driven by the subject driver was presented to the driver. When the system operated normally without delay time, the notice sound and visual icon displayed on the monitor were presented to the driver 5 s before the collision (TTC = 5 s). The icon notifying the driver about the oncoming vehicle was displayed on a 7-in. monitor installed in the upper part of the instrument panel of the driving simulator at the same time as the notice alarm sounded.

2.3 Experimental Condition

Initially, the experiment was set up with a normal condition in which the information was presented to the driver 5 s before the collision (TTC=5 s). In addition to this normal condition, two other conditions were set up in which the timing of information presentation was delayed for 3 and 4 s, respectively. In these delayed conditions, the information that notified the driver about an oncoming vehicle was presented to the driver when the TTC was 2 and 1 s, respectively. In the condition in which information was presented with a 4-s delay, the driver was presented information only after he/she could visually detect the oncoming vehicle. The subject drivers were not informed that there would be a delay in presenting this information. After the information was presented in normal conditions at TTC = 5 s to each subject driver nine times, the information was presented once with a delay at the end of the experiment.

2.4 Subject Drivers

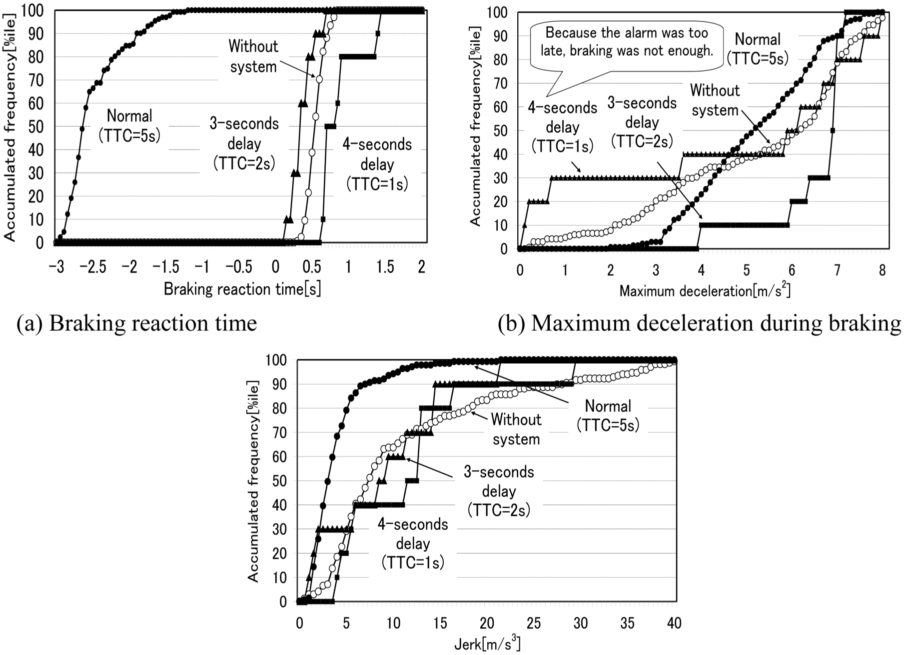
Twenty men participated in these experiments as the subject drivers. Their average age was 21.8 years and the standard deviation of their ages was 0.7 years. The experimental study in the driving simulator was started after the test subjects gave their informed consent one-week before the experiment and just before the experiment started.

3 Collision Avoidance Behaviour of the Driver

3.1 Braking Behaviour to Avoid Collision during the Simulator Investigation

In order to construct the database for the simulation that modeled the braking behavior of drivers in time series simulation, the subject drivers' behavior was investigated. The accumulated frequency distribution for each analysis index that explains the driver's braking operation is shown in Figure 1.

First, we focus on the braking reaction time. The initiation timing of the subject drivers' braking operation was delayed when there was a delay in presenting the information to the driver, compared with the condition when the system operated normally. When the information was presented to the driver without delay at the timing of TTC = 5 s, the driver started braking at the earliest time. Therefore, when the information was presented to the driver at the timing of TTC = 5 s, the maximum deceleration and average jerk were smaller. The braking reaction time to avoid the collision after the information presentation was extremely short in a condition with a 4-s delay. In the experimental condition of a 4-s delay, information was presented to the driver 0.6 s after the moment when the driver could view the vehicle at the traffic intersection. When the information was presented to the driver at TTC = 1 s in the experimental condition of a 4-s delay, the subject driver was able to visually detect the crossing vehicle before the information was presented to the driver. Thus, the driver started braking to avoid a collision with the crossing vehicle before the information was presented to the driver.



(a) Braking reaction time

(b) Maximum deceleration during braking

(c)Average jerk during deceleration

Fig. 1. Drivers' braking behaviour to avoid collision with a crossing vehicle at a blind intersection

The database which quantifies the characteristics of drivers' braking behavior was inputted into the driver model that was constructed by the authors in this study, and the collision avoidance behavior of the drivers was simulated by applying a Monte Carlo simulation method which could conduct the time-series simulation of the braking operation of the drivers. This simulation analysis demonstrated the collision frequency quantitatively in each condition. Based on the results of mitigation level of traffic accidents, we were able to clarify the delay time of information presentation that is acceptable in reducing accidents.

3.2 Simulation of the Braking Behaviour of Drivers at Traffic Intersections

While estimating the effect of utilizing the collision avoidance system to reduce accidents, a higher level of accuracy of the estimation should be maintained. For this reason, it is necessary to conduct the experimental study as many times as possible so that a statistical confidence interval; i.e., the error of estimation, becomes as small as possible. In this research, the driver model for simulating the braking behavior at the blind intersection was constructed in order to quantify the collision mitigation ratio during the use of information presenting systems used for collision avoidance. By using this driver model, we simulated the behavior of 10,000 avoidances of collisions in critical situations. The variance of drivers' behavior for each delay time for presenting information by applying the Monte Carlo simulation was investigated. In a simulation study, if the statistical confidence interval is small enough and the statistical reliability is maintained high enough, the collision mitigation ratio is quantified. By inputting the driver data concerning braking reaction time, maximum deceleration and averaged jerk in the simulation model, the change of collision-avoidance behavior of drivers and the effectiveness of information presentation were investigated through Monte Carlo simulation.

3.3 Quantifying the Collision Frequency

By using the driver model, the collision frequency was quantitatively investigated for each experimental condition with different levels of delay time for presenting information. The investigation results concerning the collision frequency and collision velocity, which we investigated through a Monte Carlo simulation by using the driver model, are shown in Table 1.

When the system operated normally without a delay time for presenting information (TTC = 5 s), the collision at the traffic intersection did not occur. By comparing the collision frequency when the system was used with the collision frequency when the system was not used, the drivers' ability to mitigate the collision at the traffic intersection is clearly shown. When the driver became used to the normal information timing (TTC = 5 s) and the information presentation was performed at a delayed timing such as 3 s (TTC = 2 s) or 4 s (TTC = 1 s), the collision frequency became extremely high.

Table 1. The probability of collision within each operating situation of the information system

Without system	7.23×10-1 (72.3%)
Normal	0.00
2-seconds delay (TTC=3s)	0.00 *estimated by use of the data in case of 3-seconds delay
3-sedonds delay (TTC=2s)	8.19×10-1 (81.9%)
4-sedonds delay (TTC=1s)	1.00 (100%)

4 Acceptable Level of Sensor Reliability Based on the Integrated Error of the Driver-System

4.1 Definition of the Integrated Error of the Driver-System

By substituting the value of collision frequency, shown in Table 1, into the integrated error of the driver-system [1]-[3], it is possible to estimate the total error for the man-machine system when the driver used the information. By comparing the collision frequency when the information was not used with that when the information was used but delayed, we quantitatively estimated the acceptable level of the delay time for presenting information. The details are as follows.

First, in Figure 2, the depiction of the integrated error of the driver-system that authors proposed in a previous research [1]-[3] is shown. We used this to analyze the accident reduction ratio of the driving assistance system. The probability of driver error is plotted on the abscissa, and the probability of a system error is plotted on the ordinate. The integrated error probability as a man-machine system can be calculated by multiplying the error probability of the driver by the error probability of the system. Each parameter is defined below.

- Ed0: Driver operation error probability when the system is not used.
- Ed1: Driver operation error probability when the system is used and the information is delayed.
- Ed2: Driver operation error probability when the system is used and the information is not delayed but the driver does not suitably evade the accident.
- Es: System error probability

The sum total of the area of the domains indicated by #1 and #2 represents an integrated error when a driver uses the information system. The area of the domain enclosed with a thick broken line (Ed0 × 1) indicates the error probability when a driver does not use the information system. A driving-support system that presents information effectively reduces accidents if the area of the grey domain (#1 + #2) becomes sufficiently smaller than the area of the domain enclosed within the dashed line.

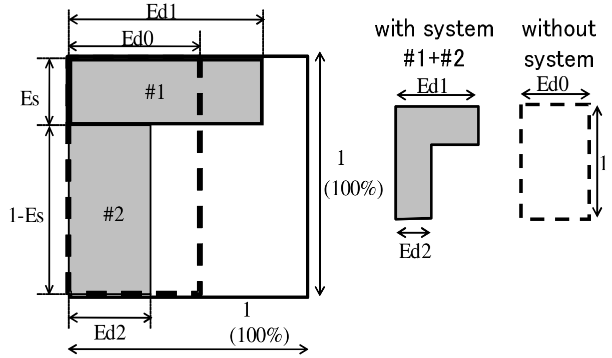


Fig. 2. Analysis model for the integrated error of driver-system

The optimal value of the mitigation ratio of collision ((“#1 + #2”) / (“Ed0 × 1”)) is an important factor in this study. The smaller risk is better to minimize traffic accidents. However, to achieve such low risk levels, it becomes more difficult to achieve the necessary high levels of reliability of the sensors. In this study, the optimal value for the mitigation ratio of collision was set at 1/100 based on the authors’ previous study regarding the const-benefit analysis.

4.2 Acceptable Level of Delay Time for Information Presentation

Based on the above model, the effectiveness of information presentation and an acceptable delay time for the information presentation are discussed. The simulation result in terms of collision frequency was investigated using the above-mentioned driver model, and the numerical values in Figure 2 were determined as follows. In this study, the optimal value of the collision mitigation ratio was set at 1/100. This means that the integrated error probability shown by the total areas of #1 + #2 should be 1/100 of Ed0. With respect to this requirement, the possible Es can be estimated quantitatively. In other words, the relationship between the delay time for presenting the information and the acceptable probability in terms of this delay time are shown in Figure 3. In Figure 3, the acceptable probability in each delay time is shown. For instance, the acceptable time frequency should be less than 0.883% in a condition in which the information is delayed for 3 s. This means that if the information presentation is delayed for 3 s and information is presented at TTC = 2 s, the collision frequency will be 1/100 of that when the system is not used. It was also clarified that if the information presentation is delayed for less than 2 s and information is presented before TTC = 3 s, the driver can avoid the collision. Therefore, it can be concluded that the delay time for presenting the information should be shorter than 2 s in order to present the information earlier than the timing of TTC = 3 s.

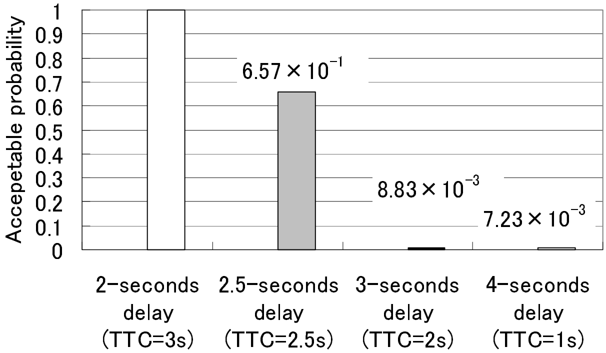


Fig. 3. Acceptable level meaning the acceptable delay time for the information presentation

5 Summary

In the experiments using a driving simulator, a database concerning the braking actions taken to avoid collisions at a blind intersection was constructed. Next, a driver model was constructed that could reproduce these collision evasive actions. By applying the Monte Carlo simulation method for this driver model, and considering the variance of driver behavior, we were able to quantitatively show the accident reduction effect when using the system. The frequency of collision and collision velocity estimated through the simulation for each condition is shown as follows.

— The frequency of collision

- Without information: 7.23×10-1, 72.3%
- Normal operation (Information was presented at TTC=5s): 0.00
- Delayed operation "3-seconds delay" (Information was presented at TTC=2s): 8.19×10-1, 81.9%
- Delayed operation "4-seconds delay" (Information was presented at TTC=1s): 1.00, 100%

The acceptable delay time for presenting the information can be estimated as follows. This analysis is based on the idea that the information system should be put into the market for practical use when the frequency of collision is less than 1/100. This frequency of collision (the total risk when the driver used the system) was estimated based on the total risk of the man-machine system, which was proposed by authors and named the 'integrated error of the driver-system'. It can be concluded that the delay time for presenting the information should be shorter than 2 s in order to present the information earlier than the timing of TTC = 3 s.

– Acceptable time frequency for each delay time

- Delayed operation "3-seconds delay" (Information was presented at TTC=2s) less than 8.83×10-3 (0.883%)
- Delayed operation "4-seconds delay" (Information was presented at TTC=1s) less than 7.23×10-3 (0.723%)

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Characteristics of Touch Panel Operation with Non-Dominant Hand in Car Driving Context

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Abstract. The aim of this study is to examine the differences of operability between dominant hand and non-dominant hand in car driving context, especially in operating of touch screen of car navigation system. For the operation of touch screen of car navigation system during car driving, the primary task is of course car driving, and the secondary task is the operation of the touch screen for a car navigation system. In this study, we drove 2 kinds of experiments; the 1st experiment was to investigate the basic usage for touch screen, and the 2nd experiment was to examine the characteristics under dual tasks; the primary and the secondary tasks. As a result, in case of single task, we could find significant differences between with dominant hand and with non-dominant hand. On the other hand, in case of dual task, we could not find significant differences so much, but only when the secondary task was not so complicated we could find statistical difference between dominant hand and non-dominant hand.

Keywords: car navigation system, dominant hand, non-dominant hand, operability, haptic, tactile, car driving context.

1 Introduction

Touch screen operation can be roughly divided into 2 kinds; those are tactile and haptic. In touch screen operation context, the word “tactile” indicates to touch the screen, and “haptic” indicates to trace the screen slipping the finger on it. Tactile can be divided into further 2 kinds, tap and double tap. On the other hand, haptic can be divided into further 5 kinds, drag, flick, pinch, pinch in and pinch out (Table 1). Especially "haptic" is new operation concept for recent years when smartphone, tablet PC, and etc. have been so common. That’s because until then operations like haptic had not been existed yet for switch or button operation. Since haptic enables more intuitive operation, tools or devices with this type of operation has been increasingly widespread. For example using iPad, we can turn a page or scroll a screen as if we turn a page of a book.

By the way, in car driving context, there are some situations in which we operate a car navigation system. Though we cannot operate the motor company original car navigation system during driving by locking mechanism, Japan Automobile Research

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 577–584, 2013.

Institute predict that in next generation smartphone and tablet PC will be used as an alternatives of current car navigation system. And actually some drivers do even right now in spite of illegal in Japan. The functions of smartphone and tablet PC, as a car navigation system, help to decrease drivers' unsafe behavior. That's because by them drivers cannot lose their way, and can eliminate the anxiety at the location where they do not know well. At the same time, it is pointed out that those could be one cause for the accidents/incidents because the touch screen operation during driving leads to the inattentive driving.

Table 1. Characteristics of touch screen operation [1]

Tactile		
T1	Tap	Tapping with fingers
T2	Double Tap	Tapping twice with fingers
Haptic		
H1	Drag	Slide with fingers
H2	Flick	Flick the screen with finger
H3	Pinch	Press with two fingers
H4	Pinch in	Reduction with two fingers
H5	Pinch out	Expansion with two fingers

A car navigation system is usually located at the middle of the dashboard; that means, in Japan, drivers operate it with left hand. Dominant hand of almost 90% of Japanese is right. That means most of Japanese drivers have to operate touch screen with non-dominant hand. Here, one simple question occurs. I wonder if there are no issues on safety. Because the operation with non-dominant hand might prevent the attention for car driving, more than with dominant hand. When using dominant hand, drivers could operate in skill-based behavior. But when using non-dominant hand, drivers cannot move their hand automatically as they want.

The aim of this study is to examine the differences of operability between dominant hand and non-dominant hand in car driving context, especially in operating of touch screen of car navigation system. For the operation of touch screen of car navigation system during car driving, the primary task is of course car driving, and the secondary task is the operation of the touch screen for a car navigation system. In this study, we drove 2 kinds of experiments; the 1st experiment was to investigate the basic usage for touch screen, and the 2nd experiment was to examine the characteristics under dual tasks; the primary and the secondary tasks.

2 Experiment

2.1 Experiment I

Summary. The task for the 1st experiment was set; that is to find the final destination using car navigation system. This task consists of 3 sub-tasks, and includes letters input (tap), scaling (double tap, pinch in and pinch out). The 1st sub-task was to input the place name of the final destination shown as figure 1. The 2nd sub-task was scaling using double tap. The default screen showed the whole Japan at first. Next, a subject expands the scale of the map until the subject has been able to find the building of the final destination, with a method of double tap (figure 2). The 3rd sub-task was also scaling but using a method of pinch-in and pinch-out. The procedure was the same as the 2nd sub-task; the default screen showed the whole Japan at first. Next, a subject expands the scale of the map until the subject have be able to find the building of the final destination, with a method of pinch-in and pinch-out (figure 3).

In each sub-task, required time and ratings of the questionnaires related to their operability were acquired as evaluation indexes. Each participant did each sub-task with each hand. This experiment was carried using iPad-mini (7.9" tablet PC). 20 male students who are between 18 yrs. and 24 yrs. (mean=21.8 yrs., SD=1.5 yrs.) were cooperated as participants. Dominant hand of all the participants was right. To check their dominant hand, all the participants took Chapman-Test [2].

Fig. 1. Input the place name (Tap)

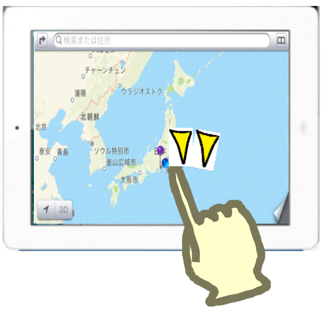

Fig. 2. Double Tap

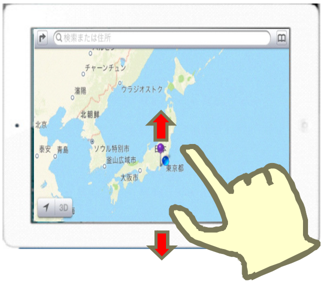

Fig. 3. Pinch In/Out

Result and Discussion. Figure 4 shows the result of required time for each sub-task, with each hand. For sub-task 1, significant differences were found between each hand ($p<0.05$). This result shows that to input characters needs more dexterity than double tap or pinch-in/out. In other words, for double tap and pinch-in/out, there are no significant differences for task efficiency (required time) between dominant hand and non-dominant hand.

In every figure, light gray shows the result of dominant hand, dark gray shows the result of non-dominant hand.

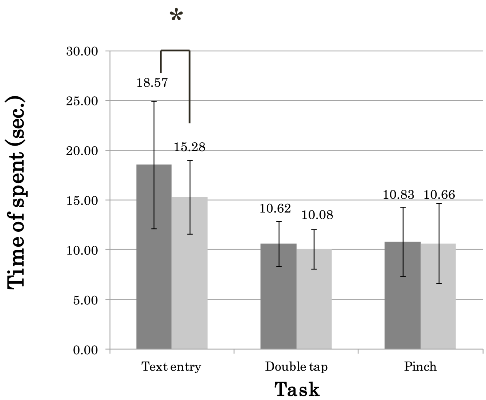

Fig. 4. Result of Required Time (light: dominant hand, dark: non-dominant hand)

Figure 5 shows the result of questionnaires for operability. The points shown in figure 5 mean the sum of the points of each question. That means; if the points show higher, it means more comfortable to operate. In each sub-task, we could find the significant differences between dominant hand and non-dominant hand ($p<0.01$). It's matter of course, when we operate touch screen with non-dominant hand, we would not feel comfort operability.

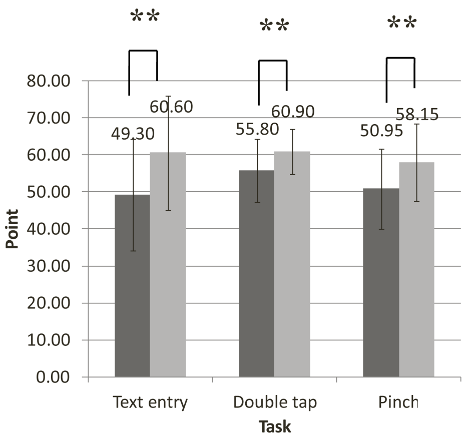

Fig. 5. Result (Points) of Questionnaire (light: dominant hand, dark: non-dominant hand)

2.2 Experiment II

Summary. We set the task introduced in Experiment I, as a secondary task. In addition, we have set a lane-keep task using driving simulator as a primary task. We used a racing-simulator game named Gran Turismo 4 of Sony Play Station 2 as the driving simulator. Each participant was demanded to keep 80kmh and to keep the lane of the oval course.

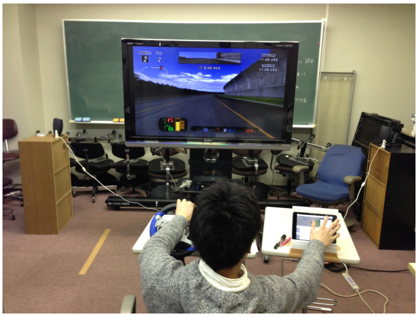

Fig. 6. Experiment II

42" liquid display was set in front of the participant. The distance between them was 200 cm. A participant sat on a driving seat with gas and brake pedal, and also the instrument panel and steering were set in front of the participant. Next to the steering, iPad as a car navigation was set on both side. Depending on the experiment condition, a participant had used either of the iPad. And next to iPad, a stimulus light was set. These are shown as figure 6. 20 male students who are between 21 yrs. and 24 yrs. (mean=21.95 yrs., SD=1.43 yrs.) were cooperated as participants. Dominant hand of all the participants was right. To check their dominant hand, all the participants took

Chapman-Test. All the participants are smartphone users, and have a driving license and drive a car with right hand drive.

We acquired the number of the errors (derailing), and the response time for the stimulus light as evaluation indexes for the primary task, and also acquired required time and ratings of questionnaires related to their operability as indexes for each secondary task. These are basically the same as of experiment I.

Result and Discussion. Figure 7 shows the result of required time for each sub-task, with each hand. There are no significant differences between dominant hand and non-dominant hand. By only the kinds of tasks, required time was changed. Input characters needs more time than double tap and pinch, and pinch needs less time than other tasks. These show, in dual task, there are not significant influences to operate touch screen with either one; dominant hand or non-dominant hand. It could be said that the difficulty of the secondary task gave some influence to the drivers.

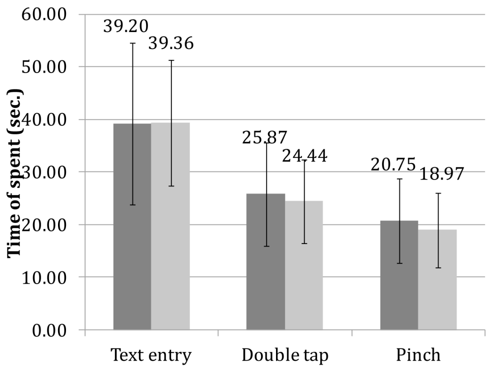

Fig. 7. Result of Required Time (light: dominant hand, dark: non-dominant hand)

Figure 8 shows the result of response time for stimulus light. Figure 9 shows the number of derailing. It could be said that both results show almost the same result as the result of required time. So we can have almost the same discussion as the above.

But on response time, we could find the significant difference in case of pinch-in/out as a secondary task. It is quite interesting that there is a significant difference when a driver's workload is less than other secondary tasks. This could be said; there are some influences of dominant hand, when the secondary task is quite simple. In other words, the effect of the dominant hand is reduced when the secondary task become more complicated to some degree.

Figure 10 shows the result of questionnaires for operability. The points shown in figure 10 mean the sum of the points of each question. That means; if the points show higher, it means more comfortable to operate. It could be said that also this result showed almost the same result as the result of required time. There are no significant relation between dominant hand and non-dominant hand, and the degrees of operability are depended on the complexity of the task. So we can have almost the same discussion as the above.

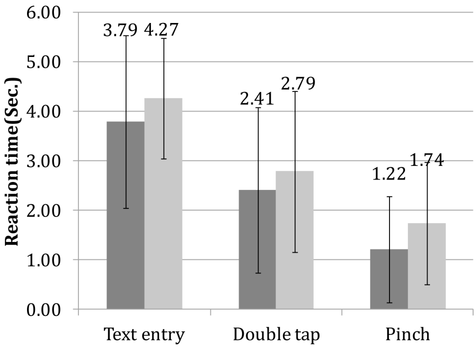

Fig. 8. Reaction Time for Stimulus Light (light: dominant hand, dark: non-dominant hand)

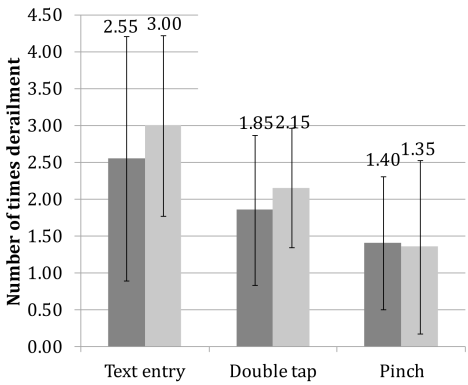

Fig. 9. Number of Times of Derailing (light: dominant hand, dark: non-dominant hand)

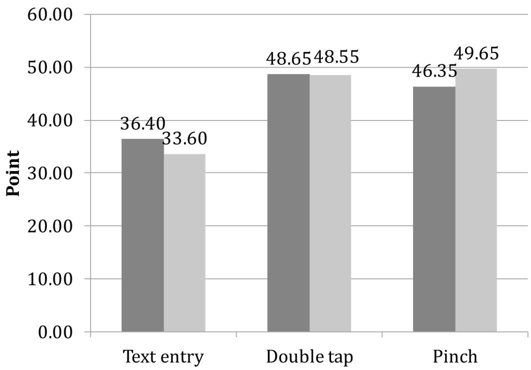

Fig. 10. Result (Points) of Questionnaire (light: dominant hand, dark: non-dominant hand)

3 Conclusion

The aim of this study is to examine the differences of operability between dominant hand and non-dominant hand in car driving context, especially in operating of touch screen of car navigation system. For the operation of touch screen of car navigation system during car driving, the primary task is of course car driving, and the secondary task is the operation of the touch screen for a car navigation system. In this study, we drove 2 kinds of experiments; the 1st experiment was to investigate the basic usage for touch screen (under only single task), and the 2nd experiment was to examine the characteristics under dual tasks; the primary and the secondary tasks.

As a result, in case of single task, we could find significant differences between the hands, dominant hand and non-dominant hand. Participants felt less operability when he operated with non-dominant hand. Required time for double tap was more than pinch-in/out, this could be said that pinch-in/out is more simple task than double tap.

On the other hand, in case of dual task, we could not find significant differences so much. Only when the secondary task was not so complicated we could find statistical difference between dominant hand and non-dominant hand. In other words, the influence of dominant hand is reduced when the secondary task become more complicated.

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Designing Simulation to Meet UAS Training Needs

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Abstract. The burgeoning use of Unmanned Aerial Systems (UASs) has required the rapid response of stakeholders to identify best practices in the selection and training of UAS operators and managers. This paper examines the Knowledge, Skills, Attitudes, and Other aspects (KSAs/KSAOs) that have been identified as necessary of UAS operators. Historical studies on KSAs are outlined and commonalities in KSAs among UAS platforms are identified. Further, best practices for KSA enhancement training, such as Simulation Based Training (SBT) and Scenario Based Training (ScBT), are described. Example training scenario development is provided as is a sample training event utilizing the outlined practices is given.

Keywords: unmanned aerial systems, aircraft, aerial, knowledge, skill, attitude, human factors, situational awareness, Department of Defense, military, scenario based training, simulation, demonstration, variable priority, control station, CRM, UAS, UAV, KSA, KSAO, SBT, SBTT, VPT.

1 Introduction

The proliferation in the use of Unmanned Aerial Systems (UAS) has become ubiquitous across both civilian and military applications. There is a demonstrated need to identify and categorize mission critical UAS operator skills and tasks based on the increased acquisition and usage of UAS by the Department of Defense (DoD) (Mangos 2011). Past military selection strategies have focused on identifying key personnel characteristics and methods to increase them within a candidate (Bowden et al. 2011), while KSAs have been identified as an important measure of the ability to perform tasking (Bowden et al. 2011). Within the defense sector, research has been conducted to identify the knowledge, skills, and abilities (KSAs) required of UAS operators (Howse 2011, Mangos et al. 2012).

Due to the variation of UAS platforms and their heterogeneous applications, dissimilar KSAs may be emphasized depending upon UAS platform and mission (Taylor 2007). However, it has been identified that certain KSAs are universally critical to UAS control and operation (Chappelle et al. 2011). Specifically, those KSAs related to computer skills, information technology, and within the cognitive domain are common to all UAS platforms more so than kinesthetic domains (Chappelle et al. 2011, Williams et al. 2011). While KSA mapping has been investigated in detail (e.g.,

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 585–595, 2013.

in the pursuit of batteries or other means to select the most appropriate operators), little research has been conducted to identify how best to model training to support KSA development, growth, and proficiency. This deficiency has been identified by the U.S. Navy, which has called for academia and industry to assist in the development of hyper-realistic, scenario-based training (ScBT) to educate and instruct UAS operators (Office of Naval Research 2012). The use of ScBT, which requires the development of a training framework to interconnect training needs, scenario design, observation, and feedback, has been shown to accelerate the acquisition of expertise (Salas 2009).

This paper focuses on identifying best practices for KSA augmentation to exemplify simulation training events to provide a framework for developing KSA enhancement curricula using procedures outlined by past researchers (Guimond et al. 2011, Mangos 2011, Mangos et al. 2012, Salas 2009).

1.1 Proliferation of UAS

The use of UASs has served to reduce the risk to humans by removing the crew from a hazardous operating environment, while enabling the remote performance of surveillance, reconnaissance, ordinance delivery, resupply, search and rescue (SAR), aerial mapping, surveying, and damage assessment (English et al. 2008, Goulter 2009, North Central Texas Council of Governments 2011, U.S. Government Accountability Office [GAO] 2008). The use and development of military group two to four unmanned platforms have experienced regular growth since 1996, with an annual use growth rate of 40% from 2004 to 2010 (North Central Texas Council of Governments 2011). This increased usage is attributable to the ability of UAS to meet the need for increased situational awareness, the capacity to save lives, effective long duration loitering, and successful implementation in foreign conflicts (e.g., Iraq, Afghanistan, and Somalia) (Association for Unmanned Vehicle Systems International 2010, Department of Defense [DoD] 2011, Gilmore 2009, Njuguna 2009, Osborn 2012, U.S. Army 2010).

Military reliance on UAS has led to the development of new capabilities, technology enhancements, and platforms (DoD 2012, U.S. Army 2010). The DoD is actively pursuing technology enhancements for their UASs that include increased interoperability, novel payloads, increased autonomy, improved interaction and collaboration, reduced fuel consumption, increased power density, heavy fuel consumption, flight profile advances (e.g., vertical take-off and landing capabilities), supervisory control, and survivability improvements (DoD 2011, U.S. Army 2010). To continue the effectiveness of UAS the DoD needs to provide sufficient training to operators and crew members (DoD 2011, Rosenberg 2012).

Current selection strategies for UAS platforms have centered on legacy procedures, tactics and methodology. Use of outdated procedures, tactics, methodologies and test batteries for selection of operators for current technologies and systems may produce operators that can adequately perform the required tasking. However, the selected operators may not possess the desirable set of KSAs needed to train and perform in an optimal manner (Howse 2011, Pavlas et al. 2009).

There are deficiencies in the existing training regimes that do not cover all aspects of UAS operations due to incorporation of new technology, misaligned communication between commanders and operators, and issues with incorporating doctrine and past experiences (Anson 2011, Bernacci 2010, Pavlas et al. 2009). However, by examining the specific knowledge, skills, and attitude (KSA) components relevant to such deficiencies it is possible to mitigate them (Pavlas et al. 2009). The challenge is to identify, classify, and address the KSA associated with new uses, technology advancements, and lessons learned from the field in the development and implementation of future training.

2 Background

2.1 Variety of Use and Design

There is a wide variety of UAS platforms, with an equally expansive set of wide-ranging capabilities currently being used by the DoD (DoD 2011, Joint Planning and Development Office [JDPO] 2012, U.S Army 2010). UASs are categorized into groups, 1 to 5, based on characteristics, including maximum gross takeoff weight, normal operating altitude, and airspeed (U.S Army 2010). The military uses for these groups include intelligence, surveillance, and reconnaissance (ISR), marine domain awareness (MDA), reconnaissance, surveillance, and target acquisition (RTSA), strike, demonstration, explosive ordinance detection (EOD), and battle damage assessment (BDA) (DoD 2011, Honeywell International 2012, Isherwood 2008, Nix and Rox 2012, Sauter et al. 2008). With the cross-development of UAS for civilian use, the list of missions has grown to include law enforcement applications, agricultural research, surveying and mapping, meteorological monitoring, platform development, informational services, aerial photography, and infrastructure inspection (Austin 2010). Each individual use and design mandates different ranking of KSA priority and necessity.

2.2 Common KSAs

Due to the unique technology, automation, control station design, and mission of each UAS type, Taylor (2006) noted that the requisite KSAs vary among such vehicles. Even in light of this, a broad spectrum of the literature indicated that there are key KSAs common to the operation of all UASs. Early investigation into the KSAs required of UAS operators tended to focus on basic cognitive skills. Studies by Barnes et al. (2000) established that oral and written comprehension and oral and written expression as critical UAS operator attributes. Phillips et al. (2003) described similar desirable attributes but added spatial processing, control precision, selective attention, and time sharing skills to the list. Building the list further, Nisser and Westin (2006) supplemented the aforementioned items with teamwork, decision making, monitoring, and situational awareness.

Through analysis of the findings of the aforementioned previous research, Triplett (2008) found that there were several KSAs fundamental to UAS operation. In particular, situational awareness, judgment, memory, spatial awareness, the ability to multitask, and visual information processing was deemed critical to effective UAS operation and control. McKinley et al. (2011) stated that vehicle control was only one aspect of UAS operation with other components being just as or more important, including mission planning, execution, environment, regulatory compliance, and judgment. Moreover, cognitive skills, such as visual search, mental rotation ability, and decision making were identified as critical for success as a UAS operator (McKinley et al. 2011).

More comprehensive analysis of the commonalities in KSAs that may be required of all UAS types was conducted by Chappelle et al. (2011) generated a ranking with the top five being: cognitive proficiency, visual perception, attention, spatial processing, and memory. In one of the most recent broad analysis of UAS KSAs, Mangos et al. (2011) listed key common KSA and other characteristics (KSAOs) of UAS operators: oral comprehension, dependability, adaptability, critical thinking, concentration, task prioritization, assertiveness, and teamwork skills. The study further identifies key tasks that operators are required to conduct across UAS types including take off, landing, surveillance, air traffic avoidance, and emergencies.

While there is a wide range of KSAOs that have been highlighted in previous studies, there are some commonalities in how these items can be categorized. This modularization is the key to evaluating potential UAS operator selection tools as well as designing UAS operator training. The various KSAOs can be blocked into knowledge, skills, attitudes, and other items common to all UAS platforms (Pavlas et al. 2009). While each UAS platform will have unique operator requirements and priorities, the aforementioned studies do indicate there are foundational KSAOs that are necessary for any UAS operator, but more importantly, there are also KSAOs that are necessary for UAS team members as many of these individuals may serve in leadership or management roles across a spectrum of UAS platforms (Tvaryanas 2006).

2.3 Training to KSAs

The underlying foundations of superior human performance lie in the possession of the KSAs necessary to successfully accomplish the tasks required to operate a system or interpret the information supplied by the system. In the UAS environment, examining the KSAs inherent to UAS training provides a simple way by which to classify the items that training should convey to operators (Pavlas et al. 2009). Knowledge components are those items required for individuals and teams to perform a task, skills are how individuals and teams actually perform them (Cunningham, 2008). It makes sense that identification of the correct KSAs needed to execute the required tasks, and training to develop and refine those specific KSAs will lead to better performance, more efficient operation of the system being employed, and greater possibility of mission success in the operational environment.

Past researchers have noted the existence of evidence regarding the ability to instruct individuals on higher-level KSAs, establishing the potential for matching KSA learning with training events in a simulated environment to assist in the creation of effective preparatory measures (Chun and Jiang, 1998). Identifying the simulation scenarios, learning objectives (LOs), and feedback mechanism, necessary in KSA analysis for training, would provide further insight and value to the UAS selection and training processes (Blair and Collier, 2012).

2.4 Matching Training Types with KSAs

In order to optimize UAS training events, KSAs should be matched with appropriate and theoretically sound instructional techniques. Certain training activities work well to build knowledge while different types of instruction are better for skill building. It is essential that combinations of educational approaches be utilized to provide efficacious and efficient training. To best pair training with the KSAs targeted for improvement, Schneier et al. (1988) advocated to begin with a training development process (TDP) that includes a thorough training needs assessment (TNA). The TDP requires first to identify the necessary KSAOs and tasks for a position and also recognizing KSAOs that have proven to be problematic in the real-world environment. The next step is to design the training by matching KSAO deficiencies with apposite exercises. Lastly, an evaluation system must be developed to ensure that appropriate feedback is available that provides a measure of the effectiveness of the training.

Pavlas et al. (2009) identified certain types of instruction that work best for augmenting knowledge, skills, and attitudes individually and also identified other effective training techniques that assist in enhancing KSAs simultaneously. For example, one type of knowledge focused training method is cross-training which individuals are required to experience roles in the UAS operations team other than their own. This gives them insight into what is expected of their original role from the perspective of another job position. It also provides individuals with improved understanding of the team necessities and dynamics. An example of a skill focused method is stress exposure training. The experience of stress in the training environment mitigates the negative effects of stress in the real-world environment. For attitudes, trust tuning training is recommended for UAS operators. During this type of activity, the trainee learns to build more trust in UAS automation systems. Whilst other types of training are more overarching and inclusive of KSAs, such as role playing, event based training, and scenario based training. The key point is that problematic or desirable KSAs need to be targeted by the careful integration of best practices of instructional methods (Pavlas et al. 2009).

3 Discussion

3.1 Modeling Training

A variety of learning and instructional theory is available as a guide for identifying best practices that can be adopted for UAS training. Because of the complex nature of UAS operations, simple practice exercises are not sufficient for KSA enhancement. Boot et al. (2010) advocated for Variable Priority Training (VPT), which trains individuals to prioritize tasks and attention in complex environments. Participants in VPT have shown more rapid improvements in learning and mastery than other types of instruction. Furthermore, VPT has been specifically prescribed for piloting, as aircraft operators must be capable of multitasking and monitoring a complex task environment (Boot et al. 2010). Two related types of training philosophy deemed applicable to UAS operator KSA development are simulation based training (SBT) and simulation-based team training (SBTT). The use of simulation for UAS operational team member KSA development has been advocated in a variety of literature (Kirkley and Kirkley 2005, Macchiarella et al. 2008). It is critical that the simulation has adequate cognitive fidelity, which refers to the ability of individuals to conduct the mental activities and processes they would use in their actual job function (Macchiarella et al. 2008). Rosen et al. (2010) noted that it is generally more helpful to go beyond simple observations, instead demonstration-based learning (DBT) proved to be a superior method for transfer of training. DBT utilizes a systematic approach to exercise the necessary KSAs through the observation of an event making it a compelling choice for UAS operations team training (Rosen et al. 2010). Another useful type of training method involves scenario construction – scenario based training In fact, these various types of training – VPT, SBT/SBTT, and DBT, all must be embedded in a simulation-based, real-world scenario to provide comprehensive, effective KSA training (Kirkley and Kirkley 2005).

3.2 Scenario Construction

The most complex part of the instructional design process is the actual development of training activities. A multifaceted approach, one that utilizes several of the aforementioned techniques, would be ideal. Kirkley and Kirkley (2005) noted that the instructional session should be anchored to a larger problem. For example, almost all UAS training will involve some sort of scenario, mission, or campaign, which can root the training tasks and connect it to reality. The task should be authentic, meaning what would normally or realistically be expected of the individual. The learning environment should be as complex as the real world so participants should have to conduct all aspects of their duties from coordinating with other individuals, to monitoring systems, and trying to avoid enemy detection. The participants should be required to think – really exercising key KSAs. In addition, there should always be opportunity for reflection after the exercise is over (Damm et al. 2011, Guimond et al. 2011, Kirkley and Kirkley, 2005, Macchiarella et al. 2008).

3.3 Example Scenario

A commonly problematic scenario in UAS operations is the handoff process. To best train for this event, a combination of DBT, SBTT, and VPT should be utilized in a simulation based environment. An example handoff should be demonstrated for reference. This should be followed by simulation-based team training in which a handoff is virtually conducted with all job functions of the UAS team being conducted in real-time by all appropriate personnel. Distractions, in terms of mission changes, communication issues, failures, or even physical conditions would create a realistic VPT environment requiring task prioritization among all participants. More KSA-building events can be added as necessary based upon perceived needs. For example, if automation issues have been identified as a common deficiency, confidence building can be made conducive by exposure to events where automation successfully helps complete a task or "saves" the situation. If over-reliance on automation is the deficiency, malfunctions can be made to occur at inopportune moments to ensure that operator and team member attention is properly prioritized and placed. For areas in which team cohesion or communication issues have been identified, cross-training would be beneficial to provide for better understanding of team member duties, actions, and responses. The holistic scenario building process should be KSA focused, team inclusive, and take advantage of simulation and different training methodologies. Scenarios can take the form of an entire mission or a specific operational event. Ideally varying combinations thereof should be used. A reflective debriefing of all team members should be conducted with the instructors immediately following the conclusion of the exercise. Such feedback is needed to reinforce the actions, or lack thereof, during the training event.

4 Conclusions

KSA analysis can be used to improve performance or determine if a subject has the requisite knowledge and capability to perform assigned activities, while identifying areas requiring additional training (Ngadiman et al. 2011, Sutcliffe 2011). KSA training is focused on placing the subject in a framework that recreates the associated task, adding tasking using previous tasks as pre-requisites to reduce cognitive loading and establishing personal significance to the subject (Masduki et al. 2010). KSAs can also be integrated into recruitment and selection strategies to identify those subjects with innovative or desirable traits (Dabu n.d., Warech 2002).With the appropriate training events, focused on the KSAs common among UAS platforms, and tailored as necessary to fit individual mission and platform needs, operators can be properly prepared to handle the wide range of real-life operations. Simulation should be used as much as possible as it is extremely conducive to UAS training events as operators are removed from the actual system and could easily be "convinced" of the realism of the instructional missions. By developing challenging, immersive, team-based scenarios, UAS operators and managers will develop the requisite KSAs to effectively and safely control their systems in the operational environment.

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Approach to Haptic Guidance Control in Steering Operation Based on Cooperative States between Driver and Control System

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Abstract. Haptic guidance provides good affinity between the driver and the assist control system for steering assist control automobiles. It is expected that haptic shared control can achieve smooth transferring of automation authority between human and automated system because it involves continuous physical interaction. Many research studies have derived smooth transferring control authority between human and machine based on such environmental factors as position in a lane. However, it is difficult to change control authority smoothly when the driver's intent changes, due to difficulty of detecting such change. Thus, the present study proposes a method to estimate the cooperative relationship between human and machine in the haptic guidance control of a steering assist system. In addition, a gain-tuning control method based on detection of cooperative status is proposed. The proposed control method is applied to a lane-keeping assist control that enables the driver to change lanes smoothly. Finally, its effectiveness is demonstrated by experiment results using a driving simulator.

Keywords: Haptic guidance control, Cooperative states, Steering.

1 Introduction

Many advanced driver assistance systems (ADASs) have been developed to reduce driver workload and to mitigate or reduce collisions. When a human operator collaborates with an automated system such as an ADAS, an appropriate relationship between human and system is important to increase the system effectiveness. For such ADASs, haptic guidance or haptic shared control has drawn much attention as a human-machine interface because it enables the human operator to interact and communicate continuously with the assist system through a haptic interface (see Abbink et al., (2012) for an overview). It is expected that haptic shared control can realize intuitive operation.

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S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 596–605, 2013.

For a human automated system to be effective, smooth trading of control authority is a key issue (Inagaki, 2003). Continuous physical interaction of haptic shared control should result in smooth transfer of automation authority between human and the automated system. In automotive safety, the haptic pedal (Mulder et al., 2011) and steering controls for lane-keeping assist, including curve negotiation (Forsyth & MacLean, 2006) (Abbink & Mulder, 2009), have been developed as examples of haptic shared controls. Abbink & Mulder (2009) demonstrated that the level of haptic authority (LoHA) could be increased smoothly based on the criticality of the driving environment by increasing the mechanical impedance of haptic feedback. Goodrich & Schutte (2008) proposed a methodology for transferring authority based on a horse metaphor. These existing studies utilized environmental variables, such as the lateral error of the vehicle in the driving lane, for authority transfer. Thus, the driver could not intentionally transfer authority in the same situation because conflict between the driver's intention and that of the automated system was not explicitly addressed.

The cooperative relationship between driver and automated system should be explicitly analyzed for the smooth transfer of authority when such a transfer is initiated by the driver or the automated system. The present study proposes a method of estimating the cooperative relationship between driver and automated system in the context of haptic shared control of steering. The proposed method is used to estimate the driver's initiative in control and conflict between the intentions of the driver and those of the automated system. The pseudo-power and pseudo-work exerted on the vehicle motion by the steering input of a driver or control actuator are utilized for analyzing the cooperative relationship between these two agents. In addition, a gain-tuning control method is proposed based on the detected cooperation status. The proposed control method is applied to a lane-keeping assist control that enables the driver to change lanes smoothly.

2 Basic Model of the Haptic Steering System

Assume that the driver firmly grasps the steering wheel and rotates it. A motor is attached to the steering shaft. The dynamic equations in 1dof motion around the rotation axis of the steering wheel, including the control actuator, are given in Eq. (1).

$$I_{str}\ddot{\theta}_{str} + b_{str}\dot{\theta}_{str} = \tau_{dr} + \tau_{str} + \tau_{v} \,, \tag{1}$$

where I_{str} is the moment of inertia of the steering mechanism around the rotational axis; scalar b_{str} is the damping coefficient of the steering mechanism; τ_{msl} is the torque generated by the human arm muscle; τ_{sys} is the torque generated by the motor of the assist system; τ_{dr} is the torque exerted on the steering wheel by the driver's hand; τ_v is the torque exerted on the steering shaft by the vehicle motion, including self-aligning torque (SAT); and θ_{str} is the steering wheel angle.

Figure 1 presents a block diagram of the whole system. Two agents: the human driver and the assist system cooperatively operate one plant or the steering mechanism in order to achieve appropriate vehicle motion.

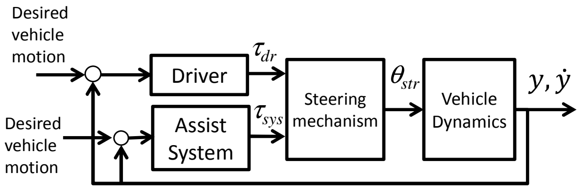

Fig. 1. Block diagram of driver-steering system

3 Cooperative States between Human and Control Systems

3.1 Pseudo-Power and Work

We investigate the effect of the two agents' steering input on vehicle motion. This study focuses specifically on lateral control of the vehicle. Pseudo-power pairs p_{dr} and p_{sys} are defined in Eqs. (2) and (3) as indices of the influence of each agent's steering input on vehicle lateral motion.

$$p_{dr} \triangleq \tau_{dr}\dot{y} \tag{2}$$

$$p_{sys} \triangleq \tau_{sys}\dot{y} , \tag{3}$$

where $\dot{y}$ denotes the lateral velocity of the vehicle.

The pseudo-work exerted on the steering system by the driver and that exerted by the assist system are given below.

$$w_{dr}(t) \triangleq \frac{1}{\Delta T}\int_{t-\Delta T}^{t} p_{dr}(\tau)d\tau = \frac{1}{\Delta T}\int_{t-\Delta T}^{t} \tau_{dr}(\tau)\dot{y}(\tau)d\tau \tag{4}$$

$$w_{sys}(t) \triangleq \frac{1}{\Delta T}\int_{t-\Delta T}^{t} p_{sys}(\tau)d\tau = \frac{1}{\Delta T}\int_{t-\Delta T}^{t} \tau_{sys}(\tau)\dot{y}(\tau)d\tau , \tag{5}$$

Here, ΔT denotes a time window for the work calculation.

3.2 Initiative of Human and Automated System

To analyze the initiative of each agent, we define the human driver as holding the initiative of the vehicle operation:

$$w_{dr} \geq \gamma^2 , \tag{6}$$

where γ denotes the offset value to waive judgment in a very small work region. It is assumed that the assist system holds the initiative when it has a negative value. It is also assumed that the system motor actively operates the vehicle system when Eq. (7) is satisfied.

$$w_{sys} \geq \beta^2 \tag{7}$$

Here, β is the offset value to waive judgment in a very small work region.

These two work values are used to define the cooperative states between the human driver and the control system as follows (Table 1).

State I: Driver-led cooperative state

The driver holds the initiative for vehicle operation with the assist control in a cooperative manner.

State II: Driver-led uncooperative state

The driver holds the initiative for steering control while the assist control attempts to operate the steering against the driver. The driver may attempt to override the system.

State III: System-led

This state includes the following two sub-states.

III-a system-guided cooperative state

The human driver is guided by the assist control.

III-b system-led uncooperative state

The human driver resists the assist control.

It should be noted that it is difficult to distinguish these two sub-states because it is difficult to measure the equivalent torque τ_{msl} generated by muscle force.

State IV: Passive

This state rarely occurs in a short time because of inertia or because SAT is dominant.

Table 1. Cooperative states between human driver and control system

		w_{dr}	
		$\leq -\gamma^2$	$\geq \gamma^2$
w_{sys}	$\geq \beta^2$	[State III] System-led	[State I] Diver-led cooperative
	$\leq -\beta^2$	[State IV] Passive	[State II] Driver-led uncooperative

This study focuses on smooth transition from state II to state I. The driver in state II attempts to override the assist control because of a mismatch between the intentions of the driver and those of the system. In such a case, it is expected that the driver's state II can be changed into state I by decreasing the assist system's contribution. This idea is applied to design the lane-keeping assist system in the next section.

4 Design of the Lane-Keeping Assist System Based on Cooperative State Estimation

4.1 Haptic Guidance Control for Lane-Keeping Assist

The torque control of Eq. (8), which is based on a preview driver model, is employed for the haptic lane-keeping control.

$$\tau_{sys}(s) = \frac{K(w_{sys})}{Ts+1}(L\phi(s) + e(s)) \tag{8}$$

Here, L is preview distance, ϕ is heading (yaw) angle in the driving lane, and e is the lateral error in the lane. Scalar $K(w_{sys})$ is the gain function, and T is the time constant. Using this controller, steering-assist torque is presented to the driver when the vehicle deviates from the center of the lane.

4.2 Gain-Tuning Control Method

The controller in Eq. (8) works well when the driver continues to drive in the same lane. However, a mismatch or conflict between the intents of the two agents occurs when the human driver decides to change lanes. Such conflict can be detected by a change in cooperative states, as defined in section 3. If the driver overrides the system for lane changing, the cooperative status becomes state II (driver-led uncooperative) (Table 1). Thus, a gain-tuning control method is proposed to achieve smooth transfer from the original lane to another lane if the driver has such intentions. In the controller, gain $K(w_{sys})$ in Eq. (8) is defined as

$$K(w_{sys}) \triangleq \begin{cases} \dfrac{K_0}{1+\exp(-a\,w_{sys}+b)} & \text{(state II)} \\ K_0 & \text{(else)} \end{cases}, \tag{9}$$

where a = 10 and b = 0.4. This control method decreases the gain according to the effort of the system w_{sys} to oppose the driver's action in state II. The sigmoid function in Eq. (9) realizes smooth shifting of the gain change.

4.3 Algorithm for Changing Lanes

When the assist system detects the driver's intent to change lanes after being overridden for a specified time, the assist system should change the target lane center and connect these two target lanes smoothly, rather than just weakening the assist control. Tsoi et al. (2010) proposed utilizing time-to-line crossing (TLC) to detect lane change intention and employ a smooth curved line as the new target trajectory connecting the old and the new target lane centers. This method detects lane change intention only using the vehicle motion in the lane, and the conflict between driver and assist system is not considered. Thus, the present paper proposes a method to detect the driver's intent to change lanes using the estimated cooperative state. A method to smoothly connect the old and new target lane centers based on the cooperative state is then proposed.

Detecting Lane-Change Intent

In state II (driver-led uncooperative), gain is decreased with our proposed method as Eq. (9). The present paper defines lane-change intent using gain *K*:

$$K(w_{sys}) \le \delta^2 , \tag{10}$$

where the constant $\delta^2 = 0.3$ is determined by trial and error.

Changing Lanes

When the driver's intent to change lanes is detected by Eq. (11), the target lane center y_d is changed:

$$y_d = \begin{cases} y_{current} - \Delta y & (\dot{y} \ge \epsilon^2) \\ y_{current} + \Delta y & (\dot{y} \le -\epsilon^2) \\ y_{current} & (\text{else}) \end{cases} , \tag{11}$$

where Δy is the lane width. Scalar ϵ^2 is introduced to set a dead zone.

It should be noted that a smooth lane change can be expected even though this method suddenly changes the target lane because gain K gradually decreases during the lane change and then gradually increases in the final part of the lane change, according to Eq. (9).

5 Experiments

5.1 Experimental Apparatus

A fixed-base driving simulator was used for the experiments. A 23.6-inch LCD display was used for visual information. The distance between the driver's gaze position and the LCD was 0.9m. The vehicle dynamics were calculated using CarSim (MSC Corp.). A 20w DC servomotor (Maxon) provided the torque generated by the assist system as well as that by vehicle motion, including SAT and viscosity. The resultant torques generated by the vehicle and the assist system were set by current control of the DC motor. A 6dof force-torque sensor (NITTA) was used to measure the torque that the driver exerted on the steering wheel.

5.2 Experimental Method

Experimental Scenario

The test course in the simulator was a 1200m straight road with 3m wide lanes. The road had two one-way lanes. The velocity of the host vehicle (HV) was fixed at

60km/h, which the drivers could not control throughout the experiments. Other vehicles (OVs) were moving at 50km/h in the left lane. The gap between OVs was 130m, and the lead vehicle (LV) was made visible when the gap between the LV and the HV was less than 80m. The participants encountered an OV in the left lane, so that the participants were forced change lanes to the right and return to the left lane a total of three times.

Experimental Design

Using the driving simulator in the test truck, the participants were instructed to follow the LV in the left lane of the two lanes in the same direction, and to overtake the LV when they felt it was moving slowly and wanted to overtake it. The participants were also instructed to return to the left lane after overtaking the LV. Five males aged 22 and 23 yrs. participated in the experiments.

The three levels in the condition of the assist system were no-system, gain-tuned, and TLC.

No-system: No assist system was installed in the vehicle.

Gain-tuned: The gain-tuned control method (i.e., the proposed system) was activated.

TLC: For comparison with the gain-tuned condition, TLC is used for detecting the driver's lane-change intention. When TLC <1.5s, the system switches the target lane to the next one. Note that Tsoi et al. (2011) utilized TLC to change the target lane, but their method connected both target lane centers using a smooth curve.

Experiment Procedure

A within-subject design was employed; thus, each participant experienced all three levels of system conditions. There were five participants. The order of the levels experienced was randomized to minimize the order effect.

First, each participant was instructed to drive the course several times in order to get used to the driving simulator. In addition, before executing the experiments at each level of system condition, each participant drove with at least 10 lane changes in order to become used to driving in the corresponding condition. The participants drove once in each condition.

Evaluation Method

Performance, effort, and activity (Abbink & Mulder, 2009) are evaluated for each condition.

Lateral error

The RMS value of the lateral error from the lane center in the straight driving area was evaluated as an index of basic performance of the haptic-guidance system.

Torque generated by driver

As an index of driver effort, the RMS value of the torque exerted on the steering wheel by the driver (τ_{dr}) was evaluated.

Steering wheel reversal rate (SRR)

As an index of driver activity, the steering reversal rate (SRR), defined as the number of changes of sign of steering angular velocity per second, was evaluated.

5.3 Results

Example of the Gain-Tuning System Performance

Figure 2 plots responses of the HV and other variables in the gain-tuned condition. Cooperative status was detected before and after lane changing; then the gain decreased appropriately during lane changing. The target lane center was switched after the gain decreased.

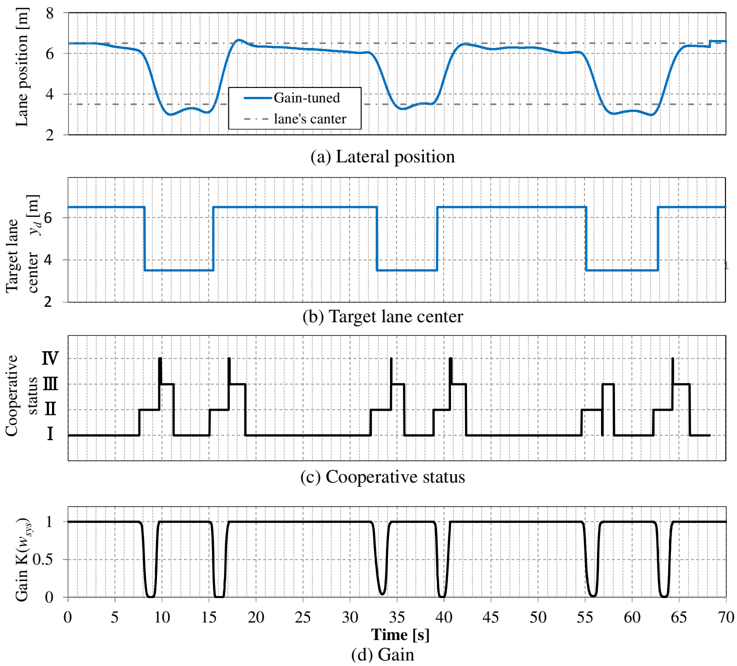

Fig. 2. Plots of the gain-tuning control system responses

Lateral Error

Figure 3 presents the lateral error. The mean lateral errors were 0.346m (SD 0.080m) for no-system, 0.216m (SD 0.122) for the gain-tuned system, and 0.114m (SD 0.087) for TLC. The repeated-measure ANOVA with a system factor indicated that the main effect of the system condition was significant ($F(2,18) = 11.5$, $p = 0.001$). Host hoc test by the Bonferroni method indicated a marginally significant difference between no-system and gain-tuned system ($p<0.096$), a significant difference between no-system and TLC ($p<0.001$), and no significant difference between gain-tuned system and TLC ($p = 0.028$). This result demonstrated that both assist systems significantly decreased the lateral error in the lane-keeping phase.

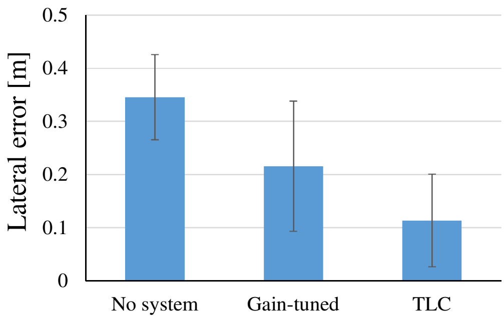

Fig. 3. Lateral error

Torque Generated by Driver

RMS values of the driver torque during lane changing were 0.535Nm (SD 0.155) for no-system, 0.483Nm (SD 0.140) for TLC, and 0.533Nm (SD 0.0981) for the gain-tuned system. The repeated-measure ANOVA with a system factor confirmed that the main effect of the system condition was not significant ($F(2,28) = 1.633$, $p = 0.213$).

SRR

SRR values during lane changing were 1.08/s (SD 0.413) for no-system, 0.866Nm (SD 0.314) for the gain-tuned system, and 0.950 (SD 0.277) for TLC (Fig. 4). The repeated-measure ANOVA with a system factor revealed that the main effect of the system condition was marginally significant ($F(2,28) = 3.215$, $p = 0.055$). Host hoc test by the Bonferroni method revealed the no significant differences among the three conditions ($p = 0.121$ between no-system and gain-tuned system, $p = 0.630$ between no-system and TLC, and $p = 0.443$ between gain-tuned system and TLC). However, the results indicated that the mean SRR was the smallest with the gain-tuned system and the largest with no-system. This result implied that that the proposed system achieved smoother lane changing.

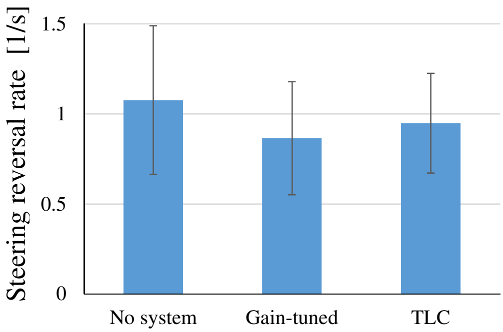

Fig. 4. Steering reversal rate

6 Conclusion

A new method to estimate the cooperative relationship between driver and assist system in the haptic-guidance control of a steering-assist system was proposed based on the pseudo-work exerted on vehicle motion by the steering input of a driver or a control actuator. A gain-tuning control method was proposed for lane-keeping assist control in order to enable the driver to change lanes smoothly.

The driving simulator experiments demonstrated that the proposed method can appropriately estimate cooperative status. The proposed gain-tuning control for the lane-keeping assist worked well with smooth lane changing. Comparison with no-system and TLC indicated that the proposed method achieved the smallest SRR (i.e., least activity and smoothest lane changing) in the lane-changing phase. The proposed system and TLC system significantly improved lane -keeping performance in straight driving with haptic guidance. These results agreed with the results of previous studies (e.g., Abbink & Mulder (2009) and Tsoi et al. (2010)). No significant difference in steering effort was observed during lane changing among system conditions. Furthermore, results of SRR analysis indicated that the proposed system achieved smooth lane-changing.

As a future study, the proposed method will be applied to other situations, including encouraging driver-in-control-loop.

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Measuring UAS Pilot Responses to Common Air Traffic Clearances

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Abstract. Using a simulated ground control station, this study documents the methods for measuring the verbal response and execution time of unmanned aerial system (UAS) pilots to direct commands from air traffic controllers (ATCos). Although prior research has examined characteristics of ATCo-manned aircraft communication, there is very little literature on response times of UAS-ATCo communication. Thus, there is a great need to examine the measured response of UAS pilots to ATCo commands given that there will be more extensive inclusion of UAS operations in the national airspace in the near future. The present paper aims to provide a methodology for measuring part of the UAS and ATCo interaction, one that can be used in future studies involving UAS operations in the national airspace.

Keywords: unmanned aerial systems, measured response, air traffic management.

1 Introduction

Unmanned aerial systems (UAS) have enormous potential for use in missions relating to scientific research, law enforcement, emergency services support, and others. In 2006, for example, NASA utilized the UAS, *Ikhana*, to peer through smoke and provide the U.S. Forest Service with valuable real-time forest fire imagery [1]. The technological capability of UAS have only increased since this time, and the recently passed FAA Modernization and Reform Act of 2012 [2] paves the way for more extensive integration of UAS into the national airspace.

Despite the increasing presence UAS will have, the precise manner in which they will interact with the current and future air traffic control framework has not been developed. It is assumed, though, that UAS will have to interact with air traffic control in a manner that is equivalent, in terms of safety and efficiency, to manned aircraft. This requirement will exist despite the fact that there will not be a pilot on board

S. Yamamoto (Ed.): HIMI/HCII 2013, Part II, LNCS 8017, pp. 606–612, 2013.

the aircraft, and that UAS have characteristics that may differ quite a bit from manned aircraft (e.g., smaller in size, slower in operating speeds, varied in terms of maneuvers that could be performed, etc.). While research into communication between manned air traffic and air traffic controllers (ATCos) exists, similar efforts have not been replicated with UAS as a focus.

Cardosi [3], for example, determined the time required for an air traffic controller (ATCo) to communicate a command to a pilot in manned aircraft in an en route environment. By reviewing voice tapes from traffic control centers and identifying traffic maneuvers, she determined the average time required for a controller to deliver a message, the average time before a pilot's response, and the duration of a pilot's acknowledgement. Cardosi found that it took, on average, approximately ten seconds for a pilot-ATCo communication to happen when accounting for the 12% of transmissions that had to be repeated due to pilot or ATCo error. Further, research has also been conducted on the effect of communication delays between manned aircraft and ATCos on controller performance and workload. Rantanen, McCarley, and Xu [4] manipulated two varieties of delay: systematic audio delay, which is the consistent delay between when the controller speaks and when it is heard in an aircraft cockpit, and pilot delay, which is the time it takes for the pilot to verbally respond following an ATCo command. They found that both audio delay and pilot delay reduced separation between aircraft in tasks where multiple communicative exchanges were required. Sollenberger, McAnulty, and Kearns [5], in a follow-up study designed to more finely determine the limits of an acceptable delay, compared a 250 ms, 350 ms, and 750 ms delay, and found that a 350 ms delay was operationally effective for air traffic communications and resulted in the best controller performance.

Considering the lack of similar investigations involving UAS, the present study was designed to establish a methodological procedure for capturing the measured response of UAS in a simulated environment. Measured response is a measurement of UAS response times to ATCo commands, and includes the following four components: (1) time for the pilot in command of the UAS to verbally respond to ATCo instruction, (2) time for the UAS pilot to begin action after ATCo instruction, (3) time for the UAS aircraft to initiate action after the pilot's command, and (4) time for the aircraft maneuver to be visible on the controller's display. A methodology to accurately capture these intervals is integral to future experimental research investigating the communication dynamic between ATCos and UAS, and to determine critical factors that differ from that of manned aircraft. The intention is that, once established, this method could be used with more elaborate experimental manipulations to further elucidate the communications relationship that ATCos and UAS pilots will have in the national airspace.

The present study captures the measured response by simulating the presence of UAS in an air traffic environment and recording the response time of the UAS to standard air traffic commands. Out of the four components of measured response described earlier, we focus on the measurement of the first two components: the interval between the ATCo's instruction and the UAS pilot's verbal response and the time for the UAS pilot to begin execution of ATCo command.

2 Method

2.1 Participants

Two retired ATCos participated in the study, in addition to fourteen IFR rated pilots. The ATCos had experience in both civilian towers and civilian TRACONs. Both indicated that they were experienced with the Multi Aircraft Control System (MACS) software [6] that was used to simulate the radar, air traffic control environment. The fourteen IFR pilots did not have any UAS flying experience, but all had experience with the Multiple UAS Simulator (MUSIM) ground control station [7] used in the study. The pilots all had flight training simulator experience, and an average of 1,171 actual flight hours.

2.2 Apparatus

The data was collected in the Flight Deck Display Research Laboratory at NASA Ames. The MUSIM-UAS ground control station was used to simulate the actions of UAS pilots. The MUSIM display consisted of a north-up map with ownship and the current filed route of the UAS (see Fig. 1). The aircraft's path was controlled by dragging and dropping waypoints along the planned route, while altitude was controlled by editing planned altitude levels at waypoints along the planned route. During the simulation the MUSIM screen did not display any other traffic. The ATCo DSR-MACS display simulated the sector used in the simulation, ZLA 20. Targets on the ATCos' DSR were depicted as a chevron icon on the display. The icon's shape and position allowed the ATCo to determine aircraft's heading and the altitude of the aircraft was displayed in its data tag. Unlike the MUSIM display, air traffic in addition to the UAS was displayed. However, the ATCo was instructed to only pay attention to the traffic when instructed to issue a traffic call to the UAS. In other words, the ATCos were not managing the traffic in the sector. The pilot, ATCo, and experimenters that were facilitating the data collection spoke to each other using push-to-talk headsets over a voice system.

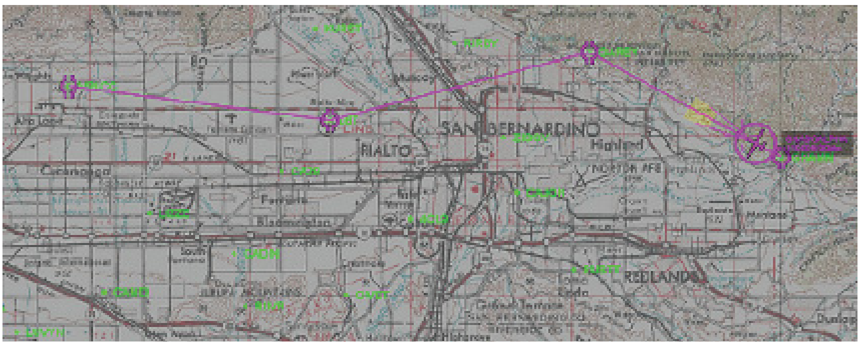

Fig. 1. MUSIM-UAS map display with a waypoint path for the UAS specified

2.3 Procedure

Pilots participated in this data collection effort following an unrelated study that used MUSIM, so virtually no training in MUSIM operation was needed. Regardless, pilots received a five minute training presentation to familiarize them with the simulation and reviewed important MUSIM procedures. Following the training presentation and prior to the experimental trials, each pilot completed an approximately five minute training scenario during which they received five different commands that included two frequency changes, one altitude change, one heading change, and one command that involved editing a waypoint. These commands were pulled from a list of 15 base commands, which were presented in a partially counterbalanced order. The commands consisted of crossing restrictions, traffic calls, radio frequency changes, route amendments and direct to waypoint clearances. The following are examples of each the 15 command types used, presented here in an arbitrary order:

- "PD-1, cross GAREY at one-four-thousand."
- "PD-1 turn left heading two-four-zero, proceed direct ZIGGY, then resume own navigation."
- "PD-1, descend and maintain one-two-thousand."
- "PD-1, turn right, fly heading one-two-zero."
- "PD-1 climb and maintain one-five-thousand, traffic twelve o'clock, five-zero miles, westbound one-three-thousand."
- "PD-1, contact center 133.25."
- "PD-1, traffic nine o'clock, five-zero miles, eastbound one-four-thousand. Turn right immediately, fly heading one-five-zero."
- "PD-1, contact tower 129.00."
- "PD-1, traffic one o'clock, five-zero miles, westbound one-five-thousand. Turn left immediately, fly heading two-six-zero."
- "PD-1, contact approach 126.30."
- "PD-1, descend and maintain one-three-thousand. Traffic eleven o'clock, five-zero miles, eastbound one-four-thousand."
- "PD-1, turn left, fly heading one-eight-zero."
- "PD-1, climb and maintain one-six-thousand."
- "PD-1, turn right three-one-zero, direct KRAIL, then resume own navigation."
- "PD-1, cross CAJON at one-five-thousand."

As noted earlier, the commands were partially counterbalanced between participants, and each participant completed two identical trials of fifteen commands. The ATCo was provided with a list of commands for each trial. However, in their list, some commands were missing specific information (which had to be changed on a trial-to-trial basis depending on the current UAS location), such as the waypoint to direct the UAS. The missing information was provided during the trial by an experimenter seated adjacent to the ATCo. Each command was issued after the MUSIM observer confirmed the MUSIM pilot was ready. The ATCo would issue each command individually and the pilot would verbally acknowledge the command and begin its execution. As the aircraft started the action on the ATCo scope, the ATCo would confirm the command was being executed on his MACS-DSR screen, and this signaled the end of the trial. The MUSIM pilot was instructed to focus only on completing ATCo commands as quickly and accurately as possible, and s/he was not performing any other UAS relevant task.

3 Data Collection Method

Timestamps were collected for verbal exchanges between ATCo and UAS pilot communication, UAS pilot actions on the MUSIM station, and observable indications of aircraft changes on video recordings of both the pilot's MUSIM display and ATCo's MACS radar displays. For each of the fifteen commands, these data allowed a detailed and accurate timeline of ATCo and UAS verbalizations and actions. In addition to the timing data, pilot workload and ATCo acceptability ratings were also collected, but this data is not being reported here.

3.1 Verbal Exchange Timing Data

Verbal exchange data that were collected included the time when the ATCos and pilots depressed and released the push-to-talk button on their headset, as well as the time that they actually started and stopped speaking. The timing data for the push-to-talk button were collected from a voice logger program that provided exact time in UTC of button presses that was written to a text output file (see Fig. 2). These UTC times were synched with a voice recording of the trial and coded as different aspects of the exchange between pilot and ATCo (ATCo beginning verbal clearance, ATCo ending verbal clearance, UAS pilot beginning verbal response, etc). Timing data for actual speech were determined by listening to a video file that displayed UTC synchronous with an audio recording of the exchanges.

Using this method, the following time points were collected for each command:

- Time ATCo depressed/released push-to-talk button in order to deliver clearance, and the time the ATCo verbally began speaking and when the ATCo ended issuing the clearance.
- Time pilot depressed/released push-to-talk button for acknowledgement of the ATCo command was collected in addition to the time the pilot verbally began speaking and the pilot's verbal response ended.
- Time that the ATCo depressed/released push-to-talk button, which signaled the detection of the executed command on the ATCo screen.

In the event that the command was a frequency change, timing data related to the pilot checking out of the original frequency and checking in to the new frequency, in addition to the response of the ATCo on the new frequency, were collected. All of these data were used to determine the interval for the first component of measured response: the time for the pilot in command of the UAS to verbally respond to ATCo instruction.

	A	B	C	D	E
1	JulianTime(Sec)	MonthDay	UTCtime	VoiceID	ON/OFF
2	1344027493	3-Aug	20:58:13	SimMgr	ON
3	1344027499	3-Aug	20:58:19	SimMgr	OFF
4	1344027501	3-Aug	20:58:21	Ghost18	ON
5	1344027503	3-Aug	20:58:23	SimMgr	ON
6	1344027503	3-Aug	20:58:23	Ghost18	OFF
7	1344027507	3-Aug	20:58:27	SimMgr	OFF
8	1344027511	3-Aug	20:58:31	kaitlin laptop	ON
9	1344027513	3-Aug	20:58:33	SimMgr	ON
10	1344027513	3-Aug	20:58:33	kaitlin laptop	OFF
11	1344027515	3-Aug	20:58:35	SimMgr	OFF
12	1344027517	3-Aug	20:58:37	UasPilot	ON

Fig. 2. Output from logger program that recorded exact UTC time of button presses used to initiate and end voice transmission

3.2 MUSIM Pilot Actions Timing Data

The actions that the pilots executed on the MUSIM station in response to the ATCo commands were coded, time stamped and recorded in a text output file. Using this output (see Fig.3), the exact time the pilots began and ended executions were recorded. For frequency changes, a video recording that displayed UTC time in addition to the frequency change panel was used to visually determine timing. These data were used to determine the interval for the second component of measured response: the time for the UAS pilot to begin an action after completion of the ATCo's instruction.

5	Type		GMT Time	Event
6	----		--------	-------
7	DCEvent:	21:00:15	22.133302	Path initially selected.
8	DCEvent:	21:00:19	27.066642	Path commit received: 1.
9	DCEvent:	21:00:48	56.033299	Path initially selected.
10	DCEvent:	21:00:52	59.766654	Path commit received: 2.
11	DCEvent:	21:01:26	93.53332	Path initially selected.
12	DCEvent:	21:01:30	97.433299	Path commit received: 3.
13	DCEvent:	21:02:40	167.233298	Path initially selected.
14	DCEvent:	21:02:44	171.166639	Path commit received: 4.
15	DCEvent:	21:03:37	225.033319	Path initially selected.

Fig. 3. Output from MUSIM station detailing pilot actions and execution times

4 Discussion

By Using the MUSIM-UAS and MACS-DSR simulation software in conjunction with the method described above, we collected timing data for various aspects of UAS pilot responses to an (FAA suggested) limited number of air traffic controller commands/clearances. With regards to the timing data, two components of the pilots' response to ATCo commands were designed to be accurately captured for further analysis: the time for the pilot in command of the UAS to verbally respond to ATCo instruction, and the time for the UAS pilot to begin action after ATCo instruction. The success of this method of data extraction provides a methodology for further experimental studies investigating ATCo and UAS pilot communication.

Acknowledgments. This project was supported by in part by NASA cooperative agreement NNX12AH23A, NASA UAS in the NAS (Walter Johnson, Technical Monitor), and NASA cooperative agreement NNX09AU66A, Group 5 University Research Center: Center for Human Factors in Advanced Aeronautics Technologies (Brenda Collins, Technical Monitor).

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