Maria Manuela Cruz-Cunha
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Communications in Computer and Information Science 221

ENTERprise Information Systems

International Conference, CENTERIS 2011
Vilamoura, Portugal, October 2011
Proceedings, Part III

Part 3

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Preface

CENTERIS – Conference on Enterprise Information Systems—is an international conference addressing the largely multidisciplinary field embraced by the enterprise information systems (EIS), from the social, organizational and technological perspectives.

The CENTERIS 2011 edition, focused on *aligning technology, organizations and people*, and was held in Vilamoura, Algarve, Portugal. This was the place where during October 5–7, 2011, under the *leitmotiv* of enterprise information systems, academics, scientists, information technologies/information systems professionals, managers and solution providers from all over the world had the opportunity to share experiences, present new ideas, debate issues, and introduce the latest developments, from the social, organizational and technological perspectives.

More than 180 manuscripts were submitted to CENTERIS, coming from all over the world. There were about 120 papers selected for presentation and inclusion in the conference proceedings. The selected papers represent more than 350 authors from academia, research institutions and industry, representing around 30 countries.

These proceedings are intended for use by academics and practitioners that want to be aware of what is currently in the EIS agenda, from research to everyday business practice. We believe that the high quality and interest of the contributions presented at the CENTERIS 2011 edition makes this an important book in the EIS field.

Please enjoy your reading!

October 2011

Manuela Cunha
João Varajão
Philip Powell
Ricardo Martinho

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Table of Contents – Part III

Serious Games and Applications for Health and Social Care

Telemedicine and Imaging Technologies

Healthcare Information Management, Medical Records and Business Processes

Decision Support Systems and Business Intelligence in Health and Social Care Contexts

Architectures and Emerging Technologies in Healthcare Organisations

M-Health

Patient Centered Design: Challenges and Lessons Learned from Working with Health Professionals and Schizophrenic Patients in e-Therapy Contexts

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Abstract. Patient Centered Design (PCD) is a particular type of User Centered Design (UCD) where the end-user is a patient that will use an Information and Communications Technology (ICT) solution for healthcare. It focuses on needs, wants and skills of the product's primary user and implies involving end-users in the decision-making and development process of the solution. e-Therapy aims to provide support to therapy sessions through ICT solutions. In the mental health arena is being used for specific therapeutic contexts and is an especially difficult environment due to specificities of the patients' conditions; the physical access to patients is restricted and, sometimes, not even possible. Thus, a PCD approach can be accomplished through the health professionals involved, applying some of the most well-known methods of UCD: interviews, questionnaires, focus groups and participatory design. eSchi is an e-Therapy tool that complements traditional practices for the cognitive rehabilitation and training of schizophrenic patients and was successfully developed using a PCD approach.

Keywords: Patient Centered Design, User Centered Design, e-Therapy, Mental Health, Interviews, Questionnaires, Focus Group, Participatory Design, eSchi, Schizophrenia.

1 Introduction

Mental disorders are amongst the 20 leading causes of disability worldwide and schizophrenia is one of the disorders identified as a priority. Currently, it affects about seven per thousand of the world adult population, mostly in the age group 15-35 years, summing up to almost 24 million people worldwide. Although the incidence rate is low, three per 10.000 inhabitants, the prevalence is high due to chronicity [1].

M.M. Cruz-Cunha et al. (Eds.): CENTERIS 2011, Part III, CCIS 221, pp. 1–10, 2011.

Schizophrenia is a severe mental disorder usually detected in the early adulthood and characterized by disruptions in thinking. People find difficult “to tell the difference between real and unreal experiences, to think logically, to have normal emotional responses, and to behave normally in social situations” [2]. Someone that endures this condition sees his/her language, perception, and sense of self, affected. Seldom, the condition includes psychotic experiences, such as hearing voices or delusions, and can impair functioning through the loss of an acquired capability, disabling the person to earn a living or continue with its studies. There is no known cure for schizophrenia, but it is treatable and allows some of those who suffer from it to have an adequate and productive life, enabling them to integrate fully into society.

Current country national policies are especially dedicated to prevent and improve mental health assistance, considering mental disorders as a public health case. One of these policies includes the digital provision of mental health information and services through Mental Health Information Systems (MHIS) [3].

e-Therapy is a subsystem of an MHIS that enables the electronic provision of an already existing and specific health service: therapy. It “is a new modality of helping people resolve life and relationship issues. It uses the power and convenience of the Internet to allow simultaneous (synchronous) and time-delayed (asynchronous) communication between an individual and a professional” Castelnuovo et al. [4]. In the e-Mental Health context there are many actors involved and contributing to the global welfare such as patients, families, caregivers and health professionals (psychiatrists, therapists and psychologists) [5]. e-Therapy may have an important role contributing not only to the patient’s treatment but also in the education process of all the actors involved. Computer-guided therapy and Cognitive Behavior Therapy is an innovative strategy that can play an important role in the future of psychological treatment [6]. When this option is available to patients, they are free to accept/reject it with all the benefits of complementing their usual and traditional therapy.

In section 2 we introduce the concepts of PCD and in section 3 we will present the therapy solution – eSchi – we analyzed, designed and implemented using a PCD approach. Section 4 provides the major challenges and lessons learned in the fieldwork. We conclude in section 5 and provide some suggestions for future work.

2 Patient Centered Design

User Centered Design (UCD) is a technique based on three principles: focus on users and tasks, measure usability empirically and develop usability iteratively. Patient Centered Design (PCD) is a particular type of UCD where the end-user is a patient that will use a healthcare solution that should meet his/her expectations [7].

2.1 User Centered Design

In the software development industry, the major aim is to obtain a high quality product that satisfies its end-users. To achieve this goal it is essential to first define what “high quality” means and then, make the product according to it. Usability is a high-level quality objective and serves as the base principle for UCD as we shall see.

The industry has already proven that the best reason for using UCD is that “if the user can’t use it, it doesn’t work”. The key differentiator of developing software is that has the “easy-of-use” feature [8-10]. IBM, Apple and Google are some of the companies, to name a few, widely known and successful that seek to provide effective, efficient and satisfying products for use in a specific context. This requires the design of an appropriate interaction and interface, achieved through a user-centered process that is only viable with a consistent organizational capability [11].

It might seem obvious that users should be involved directly in projects, but when real-life projects are concerned, several difficulties arise [12]. For instance, many organizations do not seem to realize the cost-benefit of involving the users early in the development process. Some argue that it has cost benefits, while according to others the usability evaluation methods are not cost effective [13].

Probably the most used definition on usability is by Nielsen and dates from 1993: "usability is about learnability, efficiency, memorability, errors, and satisfaction” [14]. The current standard definition of usability since 1998 is as follows: “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” [15].

The most referred standards related to usability are the ISO 9241 series. This series is concerned with describing usability and the ergonomics in a specific context of use. They include the human-system interaction of the systems and the guidelines specifically for the design of accessible software including the elderly and persons with disabilities. Another standard, the ISO 13407 refers to specificities of designing usability, the process of achieving usable systems [16, 17]. The standard identifies the following four general principles that characterize the user-centered design: the active involvement of users and a clear understanding of user and task requirements, an appropriate allocation of functions between users and technology, the iteration of design solutions and multi-disciplinary design.

UCD activities appear arranged into the four typical software development phases: analysis, design, implementation and deployment (Fig. 1). After identifying the need for human-centered design, the designer team should plan which methods to use during the distinct phases of the approach (step one). Teamwork and communication are extremely important. Knowing the environment where the product will be used is essential for a good outcome (step two). In order to determine the tasks that users should accomplish when using the product (step three), the team should define users and personnel involved in the system and this specification can be achieved using direct user observation or contextual inquiry [19, 20], participatory design [21, 22], interviews, questionnaires [23], focus groups or brainstorming.

Several usability inspection methods, including heuristic evaluation, user satisfaction methods, and the performance measurement method evaluate the proposed design (step 5). The whole idea in testing is to assess the degree of achievement of requirements. In order to answer a simple question: “does this design support the user’s tasks?” it is required to diagnose eventual usability problems and evaluate the achievement of the objectives. On the other hand, narratives and explanations of study participants through the think-aloud method or post-study open-ended interviews are some of the techniques mostly used for these systems’ evaluation.

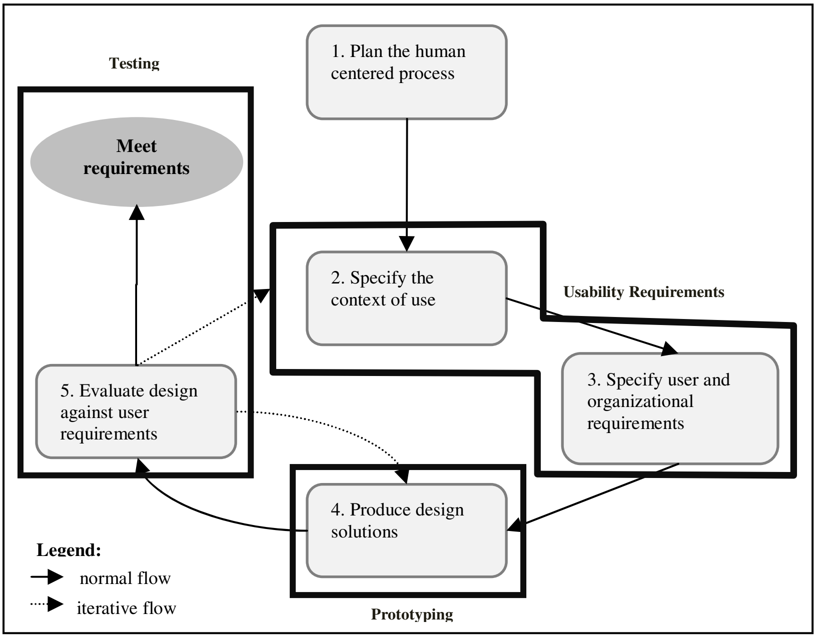

Fig. 1. User Centered Design Process (adapted from [18])

2.2 Patient Centered Design for Mental Health Contexts

Patient Centered Design (PCD) is the designation of a methodology that implies involving patients in the decision-making and development process of an ICT solution. When using such a methodology, patient empowerment occurs and they start to have an active role that allows them to make choices and provide input regarding their treatments [7].

This approach to design is tightly linked to the current development of patient-centered healthcare delivery processes. However, introducing ICT in clinical settings should be done cautiously, namely to support clinicians tasks and augment the services' delivery to patients [24]. In fact, this approach is a fundamental piece to provide Healthcare ICT solutions and implies partnerships between practitioners, patients and families/caretakers.

In summary, PCD is a particular type of UCD where the end-user is a patient that will use a healthcare solution that should meet his/her expectations. Thus, PCD starts by listening to the patient's needs and requirements besides considering the social and technical context for the implementation of the product.

Reported benefits of PCD include the increase of the communication between the healthcare figures. There should be an interest in linking organization goals with the user goals and the features delivered by the system. Examples of undesirable outcomes include missing deadlines, poor user adoption and not achieving the expected benefits.

When it comes to the mental health arena, there are already some services available in the field, but there is no evidence of a sound and systematic method to develop ICT for schizophrenia or psychosis patients [20, 25].

3 eSchi – an e-Therapy Solution

eSchi is a web-enabled multimedia system intended for use in therapy settings. The system provides a commonplace for patients, health professionals and caregivers to relate and communicate with each other. eSchi allows the management of patients and therapy sessions, as well as carrying out sessions and visualizing the results obtained in those sessions. While patients can conduct cognitive-related activities, where the system plays a more entertaining role, health professionals can monitor and visualize the patients' performance in e-Therapy settings.

The eSchi system contains a set of multimedia tools, available online, that enable schizophrenic patients' cognitive enhancement [26]. The tools help patients in their cognitive rehabilitation and therapists in their work. This e-Therapy tool can be seen as a learning tool to teach and train schizophrenic patients to acquire basic skills that were once lost because of the cognitive impairments suffered. Patients are able to train their motion skills with simple games for the usage of the mouse: moving objects around, clicking on specific places and dragging and dropping objects. There are also basic cognition activities related to recognition and association of objects. Accurate data regarding the patient performance, during the training is recorded. Hence, it is possible to know the patient behavior during a specific activity.

Therapists are able to manage information regarding patients' data, see patients' performance and configure sessions and activities for the patients. After conducting the session with the patient, the therapist is able to see the patients' performance during a specific period of time and program future sessions according to the observed results.

3.1 The Fieldwork – Two Case Studies

We had the privilege to deploy eSchi and conduct our study and test it, under real clinical settings. This is something incredible difficult to achieve in the mental health context [27]. The fieldwork was planned according to the well-known case study methodology proposed by Yin [28]. Two case studies, similar to a sister-study, were defined and shared their design, keeping several aspects of the study with minor changes.

Case Study at Hospital Sant Joan de Déu. Sant Joan de Déu is a religious order that started back in the XVI century and that assists and helps the ill and the disadvantaged. The Hospital Sant Joan de Déu (HSJD) is located close to the city of Barcelona. The medical team of the HSJD was a part of the development team of eSchi. The initial set of multimedia activities was defined with the help of that team and the base language support for the eSchi system was Spanish. The first actual implementation of the system was done in this facility.

Case Study at Hospital Magalhães de Lemos. The Hospital Magalhães de Lemos (HML) is located in Porto and is considered as a psychiatric-specialized hospital and is the only one that serves the north of Portugal. The hospital directs its available services to anyone that carries a severe and chronic mental illness; and with difficulties in the psychosocial functioning and community integration. It ensures the provision of rehabilitation services to patients and social reintegration to those that have no familiar back support and have been living in the facilities for long periods. The second implementation of the system occurred at their facilities.

Design of both case studies. The first step was to conceive an implementation protocol plan that defined the steps to follow in the usage of the eSchi system. The protocol contained a brief explanation of the procedures and a plan with the needed resources: human and temporal. It proposed a three-week period intervention subdivided into three distinct and sequential steps, relative to the usage of the system. The idea was to identify the expectations regarding the usage of the system and obtain some demographic data. After that, a period with a frequency of one session per day during which the eSchi system is used as a complement in the therapy, developing cognitive activities. The users' opinion and satisfaction with the usage of the system throughout the session and after the study were also identified.

4 Challenges and Lessons Learned

The eSchi system was implemented, deployed and data was collected from two distinct case studies. The idea was to provide two similar sites in which the system would be implemented but reality is actually quite different. It is almost impossible to ensure the same type of conditions from site to site. Each site has its own unique conditions that include aspects such as an internment ward or an ICT laboratory, and schizophrenia typologies present. The number of patients that engaged in the study was considerable different, from site to site, and even the diagnosis, the typologies of schizophrenia and schizoaffective conditions were distinct.

"There are no illnesses, only patients" is a popular saying in the mental health area. Each patient has its own individual and unique condition and cannot, and should not, be grouped into a cluster either in diagnose or treatment. This is the belief of all the health professionals in the mental health field that we had the opportunity to meet. The patient individuality should be respected. While this proves to be highly considerate for the patients and improve the environment lived in the facilities, this is also one, if not the major cause for the harsh situations found when trying to conduct valid research studies, such as this one.

Despite the fact that schizophrenia is a chronic illness that, at present, has no scientific evidence on cognition improvements, the indicators collected by the system attempt to provide some insight into the patient's behavior within a session and throughout a sequence of episodes in time. The results seem to show that patients seem to develop their ability through training. Repetition of the same activities though a certain period seems to improve the outcomes.

Some free-text comments, mainly made by the therapists, requested new and improved activities, based on their perception on the e-Therapy sessions where eSchi was used. Therapists considered eSchi as a valuable tool to be used in their e-Therapy sessions and even requested that improvements were included in future versions. This includes new and more challenging activities. When both profiles (therapist and patient) are compared, it is obvious that the satisfaction level after using eSchi is superior for patients. This can be explained by the fact that therapists had higher expectations regarding the evolution of the tool, and the satisfaction score of using the system was strongly influenced by this fact. These are the lessons we learned:

4.1 Plan the User Centered Process

The eSchi system is the resulting product of an e-Therapy project conceived by a multidisciplinary team with health professionals from the HSJD in Barcelona and information systems analysts, designers and developers of the Polytechnic University of Catalonia (UPC) and of the Polytechnic Institute of Leiria. Both teams shared the dream to improve the quality of life of schizophrenic patients and the quality of their therapy sessions while recurring to new information and communication technologies.

4.2 Specify the Context, User and Organizational Requirements

There were many informal conversations and meetings to conduct a contextual inquiry before the first focus group session actually occurred. In this first official meeting, the initial requirements for the system were defined. The meeting was recorded on camera and later a written transcript was made.

The focus group recognized the system's magnitude and complexity and settled in a prototype approach to the system that complied with the first basic functionalities that could be provided to both patients and the health professionals. After this set of focus group meetings it was extremely important to include all the stakeholders including final users as a part of the entire process; to listen and take into consideration their ideas and professional remarks.

Hence, the system was defined in simple UML diagrams that included the results of the meetings. The diagrams were accepted and understood by all the participants in the focus group. This allowed the non-health professional members of the team to have a more accurate perception on the aspects of a traditional therapy session, including its real surroundings.

4.3 Produce Design Solutions

In this phase of development of the system, we designed it according to the knowledge we had gathered in previous phases. The development team presented a prototype of the features implemented and collected feedback from the health team concerning the usability and features provided by the system. Several *ad hoc* tests were conducted to enable a participatory design.

In order to collect data from the study, both questionnaires and the eSchi system itself – as the monitoring tool – were used. The custom questionnaires used, besides obtaining an initial set of demographic data, were intended to obtain users' expectations before using an e-Therapy tool and their opinion/satisfaction after using the eSchi system. Usage data of the eSchi system was collected in an automatic and transparent way. All the questionnaires used; the custom questionnaires, the After Scenario Questionnaire (ASQ) and the Computer System Usability Questionnaire (CSUQ) were carefully translated into the users' native tongue, either to Spanish and Portuguese. All the translations were verified and validated by the medical team inside the development team. Besides, the application accommodated multilanguage support and became available in both languages.

To assure confidentiality of the study applicants, prevent possible personal detection upon data analysis and maintain the integrity of the information being gathered in the study, a unique codename was given to each user. The codenames endorsed were, for the simplicity of the process, also used as the usernames to login in the eSchi system. The only person that can establish the mapping is the psychiatrist, which is obliged to comply with the standard patient-doctor confidentiality rules.

4.4 Evaluate Design against User Requirements

In order to obtain some adequate and formal feedback before deploying eSchi into a real setting, a heuristic evaluation was conducted [14]. Despite several usability techniques have been scientifically proven to be more adequate and better, as far as results are concerned, they are more time and money consuming than this "discount usability engineering" approach. A test scenario was created to evaluate eSchi's patient module usability. Seven evaluators were asked to conduct a heuristic evaluation to the module and the information needed to conduct the evaluation was sent to each one. Each evaluator was asked to provide a written report with the issues examined, severity levels and further observations they considered useful. A new release of the system was published [29] and the system was considered ready to be deployed in a real setting. The functional tests that mapped each user requirement to the actual features of the system were conducted directly in the field with the final users – patients and therapists.

Some special considerations were taken regarding the user selection for the studies.

In Barcelona, only one psychiatrist applied to take part in the study: the supervisor for the schizophrenia ward in the hospital. In Porto, only one therapist applied to take part in the study: the leading person of the occupational therapy section of the hospital. Both supervisors made the patients' selection using as a major criterion the need for cognitive rehabilitation. Hence, the inclusion in the group of users was made upon consideration of having a positive impact on a patient's treatment.

The first step to enable the study enrolment was the establishment of a physical scenario where the study could occur. In Barcelona, an ICT laboratory was established, where a limited number of computers, three, became preferred eSchi access points. Each desktop computer was equipped with a keyboard, a mouse and a set of headphone devices. The laboratory was located in the hospital's ICT room that has a free access policy for most patients. In Porto, the hospital has an ICT room that has a limited access policy: only patients engaged in computer related activities can access the room and under a specific schedule. There is always the supervision of an informatics technician in the free access periods. It was guaranteed that each desktop computer could become an eSchi access point. This scenario setting was easier to conduct than the first one in Barcelona.

By the end of the first week of usage of the eSchi system in Barcelona, with the psychiatrist conducting sessions with the patients, several modifications to the application were requested. The suggestions came directly from the psychiatrist and revealed the patients' reactions while using the eSchi system. According to the psychiatrist, some users were highly sedated and were unable to click the mouse buttons in an autonomous way. It was suggested that the application received key strokes from the keyboard and allowed a better flow of the activities. The updates made to the application concerned the usage of the mouse and keyboard enabling a more efficient use of the system. The changes were implemented and readily applied, and, at the beginning of the second week, the users started using the new version.

By the end of the first week of a complete engagement from the users in the usage of eSchi in Porto, conducting sessions, the study went through a pause. According to the therapist, one of the users was discharged of the services, thus leaving the program and the other users required a higher level of complexity for the activities proposed. Hence, the technical team proposed a new set of activities to the therapist. This was the turning point in the deployment and evolution of the eSchi system, which allowed us to end our study. According to the therapist, it was time to develop and deploy new activities.

5 Conclusions and Future Work

To conclude, we find that there are two important aspects that prove the success of eSchi. First, all the users that engaged in the study asked for further enhancements of the system, requesting new activities. This reveals their interest in keeping on using the system. Secondly, eSchi is currently in use in a third site of the HSJD by a third group of new users. This application of the system occurred through a professional recommendation of the therapist of the first site that found eSchi suitable for her professional usage and worth of recommendation for other professionals in the area.

The successful deployment of eSchi can be partly attributed to the PCD approach used. It started by listening to the patient's needs and requirements besides considering the social and technical context for the implementation of the product. The method implied the active engagement of end-users in all the design phases starting from early in the lifecycle development process. The PCD approach increased the communication between the health professionals that were involved in the project and the development team as the topics described above express.

All the lessons learned can and should be used in the future development of MHIS in order to accomplish systems that are actually used in the field.

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A Medicosocial Videoconferencing Tool for the Elderly, Impaired and Long-Term Care Patients

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Abstract. In this paper we present TAM-TAM (Tele Assistance and Monitoring), a tool targeted to the elderly, impaired and long-term care patients. It provides social support, remote consultation, remote monitoring and training or rehabilitation group sessions through multi-user videoconferencing. TAM-TAM relies on a simple and minimalist interface based on accessible standard web technologies and open video streaming solutions compatible with traditional (desktop and laptop) PCs as well as last generation tablet PCs. TAM-TAM proves useful to be deployed at nursing homes, group homes and even private homes for alleviating the patients' loneliness and depressive status and improving their emotional and social support thanks to their interaction with their families, social carers or psychologists. On the other hand, it is also used for providing remote medical services to give advice and determine whether it is needed to take a further displacement.

Keywords: videoconferencing, teleconsultation, social care, nursing home, group home, elderly

1 Introduction

Over the last decades, the accelerating pace of the world's population aging is remarkably changing the demographic distribution of population. In fact, the last International Population Report issued by the U.S. National Institute on Aging [1] shows that by 2020, for the first time in history, people aged 65 and over are expected to outnumber children under age 5.

In Europe, according to [2], from 2005 to 2030 the number of Europeans aged over 65 will increase by 52.3%, resulting in 40 million additional old citizens, in other words there will be more than 100 million people older than 80 years by 2020.

On the other hand, it has been widely proven that the ageing of the population and changes in lifestyle become two key factors in the growing prevalence of chronic disorders [3], which put in risk the current healthcare system since it is more focused on the treatment of acute diseases. In 2002, the World Health Organization (WHO) launched the Innovative Care for Chronic Conditions (ICCC) initiative, which formulated the basic principles and strategies to improve the management of chronic

M.M. Cruz-Cunha et al. (Eds.): CENTERIS 2011, Part III, CCIS 221, pp. 11–20, 2011.

patients. Those principles include: disease prevention, an increasing implication of the patient and relatives in the management of the disease and a joint work between primary, secondary care and all the actors involved in healthcare.

In this context, there is a need for technological tools that help to deploy this integrated care for chronic patients, i.e. the elderly, impaired and long-term care patients. Hence, videoconferencing postulates as a very powerful technology to enhance social support, loneliness and depressive status of those collectives [4].

According to [5], Internet technologies would be more used if they were better adapted to the elderly and that the main reasons adduced by non-cybernauts for not using the Internet are the difficulty (71%) and the effort required for learning how to use it (60%). Between the proposals for improving the usage, price and simple interfaces are considered to be prominent.

In the last years, with the increasing development of the tablet PC market, very few companies or initiatives have taken benefit of the new capabilities provided by those devices, while most of them are proprietary, as [6]. Tablet PCs have long-lasting batteries and capacitive screens that ease their use with respect to PCs and portable PCs. Moreover, web technologies have evolved in such a way that it is possible to design very intuitive and usable interfaces. Tablet PCs can be easily transported and they can be charged, sustained and connected to external displays by using docks.

In this paper we present TAM-TAM (Tele Assistance Monitoring), a tool that combines the advantages of a web-based approach with the versatility and the affordable cost of tablet PCs. TAM-TAM offers an intuitive interface for the elderly, impaired and long-term care people as well as for health professionals to provide social support, remote consultation, remote monitoring and training and rehabilitation group sessions through multi-user videoconferencing.

TAM-TAM has been developed in the context of a working group lead by our research group [7] in coordination with the Social Services Cohesion Board depending of the Girona's Council. This working group, called "ICT, socialization and active ageing" explores and promotes new efficient ways for supporting the elderly, dependent and impaired people through the use of ICT technologies.

2 Related Work

There are several initiatives and projects dealing with the development of devices and applications devised for the elderly, impaired and long-term care patients. Next, we provide a brief overview of some projects that are focused not only on the medical application but also on the social aspects.

ALZ-AVANZA [8] is a project funded by the Spanish government that is focused on developing a platform to be run on mobile devices to help the elderly and dependent people to improve their autonomy. It developed a virtual assistant for providing reminders (medication, dates, etc.), spatial location (GPS), monitoring of biomedical parameters, panic button and transmission of personal health information from/to the mobile. Videoconferencing is not included due to the device's limitations.

ATTENTIANET [9] is a project funded by the EC under the e-TEN market validation program. ATTENTIANET is also devised to elderly and dependent people and includes audioconference, mobile devices, spatial location, panic button, etc. It can be framed into the ambient assisted living area. ATTENTIANET centralizes the system in the user's TV by means of a specific set top box.

Colabor@ [10] is a project developed by Telefónica I+D. Colabor@ built a platform that enables professionals to share health information such as documents, images and videos and includes single or multi videoconferencing based on Skype. From the client perspective, it is based on the use of large tactile screens and some specific software installed in the client's device.

On the other hand, there is also a wide range of videoconferencing applications, either open or proprietary that could be adopted for bring integrated in a new application. In general, videoconferencing solutions can be classified into two types: dedicate systems and desktop systems.

Dedicate systems consist of an integrated equipment including all the interfaces with external devices (i.e. camera, microphone, speakers, display) and a hardware or software codec for the audiovisual digital transmission. Some examples of manufacturers are Sony, Tandberg, Polycom and Cisco, amongst others.

Desktop systems are applications that can be installed or run on a computer and are very diverse in nature and number. Next we describe some of the most relevant to integrate the videoconferencing functionality into the TAM-TAM framework.

Ekko, TokBox and Vawkr are free videoconferencing tools that can be easily embedded in a web site or as part of another application. However, they lack some functionality such as recording conferences or sharing documents, and they are not open source, so they cannot be freely modified or improved.

Some relevant payment solutions are Adobe Acrobat Connect Pro and ViewCat, both flash-based, and Skype, which will in short support videoconferencing only for Verizon Wireless devices.

Amongst the open source solutions, we need to mention OpenMeetings, a flash-based solution that includes shared desktop, blackboard, and multi videoconferencing. However, the complexity of the application odds with the TAM-TAM goal of simplifying user interfaces and providing a very intuitive framework.

Finally, we need to mention that HTML5 is a recent standard that could be used in the next future for developing videoconferencing solutions. Currently, the specifications and implementations of HTML5 in different browsers support the streaming of video and the rendering in the same browser without the need of external plugins. However, although accessing the local camera for streaming the video is still not solved, some experiments prove its feasibility [11].

3 System Architecture and Functionality

3.1 System Functionality

Current main functionalities present in TAM-TAM are described in detail next.

Videoconferencing. It is the central element in TAM-TAM, as it is needed for providing telemonitoring and teleassistance health and social services. TAM-TAM enables the audiovisual interaction through videoconferencing in a 1 to 1 mode or in a N to N mode. This means, that it has been designed to support videoconferencing between two parties as well as multi videoconferencing. Videoconferencing has proved to be very useful both from the medical and social perspective. On one hand, from the medical point of view, it enables a closer remote monitoring of the patients while improving their compliance to the prescribed treatment or therapy [12]. On the other hand, from the social perspective, it alleviates the patients' loneliness and depressive status and improves their emotional and social support thanks to their interaction with their families, social carers or psychologists [4]. In turn, multi videoconferencing can help to go one step beyond and enable the practice of training or rehabilitation group sessions (e.g. occupational therapy), improving the feeling of belonging to a group of people with similar problems and concerns.

Calendar, messages and notifications. A critical feature when dealing with the elderly, impaired and long-term care patients is the presence of a reminder mechanism for activities or actions that need to be carried out punctually or periodically, such as drug administration, exercises to be carried out, medical appointments (physical or by videoconference). In TAM-TAM, we offer different interfaces for that purpose. First, we provide a calendar-like interface for editing and consulting any activity or action that is linked to a certain date, time and periodicity, what we call a notification. Each notification can be configured with an urgency degree (low, medium and high), which determines whether it will trigger a visible warning when the user accesses the TAM-TAM application or whether it will be kept in the calendar to be further consulted. Then, we also provide a mailbox-like interface for enabling users to send customized messages to any other user associated to them. Calendars become a very powerful tool when people belong to nursing or group homes, which are monitored by specific associations, as they can be used to manage the patient's agenda from the association itself. Edition interfaces can be configured to be accessible to all or part of the application users, depending on their role (e.g. notifications could be generated by professionals such as physicians or social carers but not directly by end users).

Instant messaging and chat. Instant messaging (IM) and chat introduce a higher complexity in the use of telemonitoring and teleassistance applications, since they need a direct interaction of users with physical or tactile virtual keyboards, which might be something not affordable for limited capabilities patients. However, in some occasions when the audiovisual interaction between two parties becomes not feasible due to temporal bandwidth constraints, it may act as a backup means of communication. Moreover, for certain type of users that do not have difficulty in using technology, this may act as an added value to establish and maintain a less formal communication with other users. Therefore, the TAM-TAM tool can be configured to provide instant messaging and chat functionalities depending on the user capabilities, through a user preference interface run by the system administrator.

User authentication. Since user authentication needs to be kept as simple as possible, a user and password approach has been adopted, offering the possibility to remind them for future accesses. When the user device (probably a tablet PC) is fully dedicated to TAM-TAM, authentication can be highly simplified by following an initial setup that bundles the application to a specific user.

User contacts. TAM-TAM offers the possibility to bundle a set of predefined contacts to a user by the system administrator as well as to add new users by sending and invitation to be accepted. The user's contact list is available to determine whether a user is connected so that a communication can be started towards them.

3.2 Architecture

The TAM-TAM system consists of two main parts: the portal or front-end, and the server or back-end, as depicted in Fig.1.

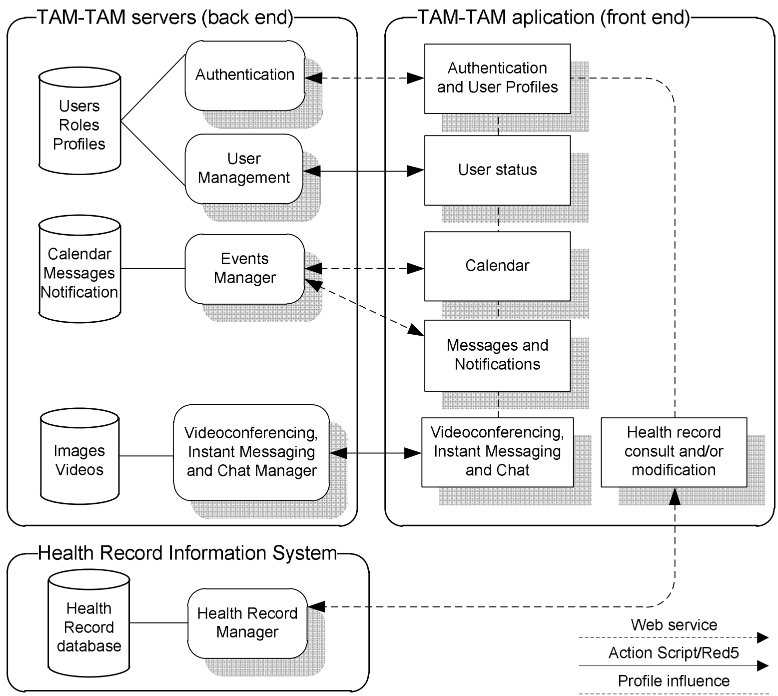

Fig. 1. TAM-TAM architecture logical components

The front-end is the application that users access, either from their web browsers or as an installed application (see section 3.3) and which offers the interface for the whole system functionality, i.e. videoconferencing, calendar, messages and notifications, instant messaging and chat, user authentication, user contacts, etc.

The back-end is composed of the modules that interact with the front-end and which obtain and manage the information stored in the system's databases. TAM-TAM currently uses two different relational databases, one for users, contacts and profiles and a different database for managing the calendar, messages and notifications related to those users. Regarding the modules, they provide the intelligence for the functionalities offered by TAM-TAM and the interfaces with the corresponding databases. For example, there is a module responsible for managing notifications, messages and the user's calendar. This module is implemented as a web service that offers the functions to store create new events, messages and notifications as well as to consult them for a specific user. The front-end makes use of those functions whenever a new notification is to be created or when a user logs into the system to consult any pending urgent notification. There is also a module dealing with the videoconference feature, which receives all the audio and video streams and forwards them to those users that belong to the same audiovisual single or multi videoconferencing. This module is a servlet running on the multimedia server.

Fig. 2 identifies the technologies being used in TAM-TAM, described in subsequent sections.

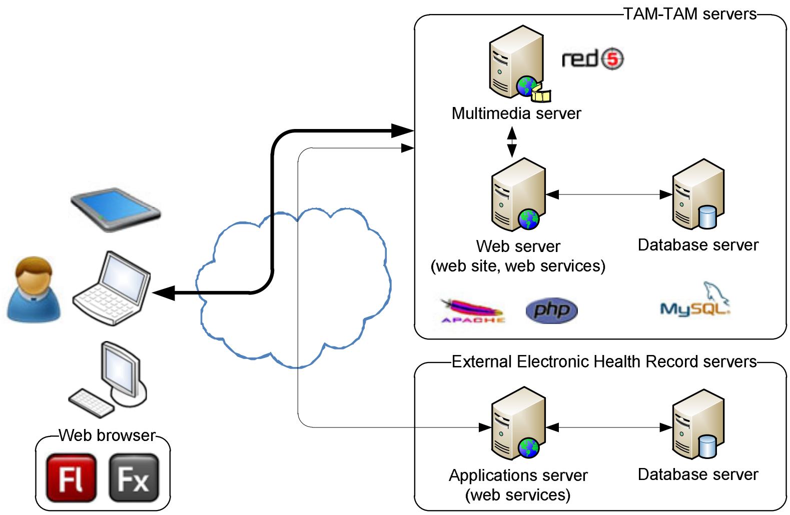

Fig. 2. TAM-TAM architecture: hardware components and software technologies

3.3 Client Technology

The technology needed for the client application fits the requirements of the so-called Rich Internet Applications (RIAs). RIAs try to enhance the user experience by offering in the web browser some features of traditional desktop applications, while making the update process transparent for the user and avoiding the reload of web pages. RIAs make use of plugins, virtual machines or sandboxes to offer additional capabilities (e.g. access to the local camera) without compromising security.

Amongst the available frameworks that are used for the development of RIAs, JavaFX, Microsoft Silverlight, AJAX, Google Web Toolkit and Adobe Flash and the most relevant and adopted. Adobe Flash has been choosen for the TAM-TAM tool, since it enables the development of web applications by using the Adobe Flex framework. Adobe Flex is an open source compiler and SDK based on two underlying programming languages: MXML and ActionScript (AS). While MXML is used for easing the design of user interfaces based on Cascading Style Sheets (CSS), AS offers an API that can be used for providing interactivity video conferencing in a simple way. AS is an open source object-oriented language similar to JavaScript based on ECMAScript. AS can be used for developing websites or web applications by compiling the implemented classes into a SWF file that can be run on the Adobe Flash Player. Whenever an MXML interface is defined, the compiler will generate the corresponding AS classes prior to generating the SWF file.

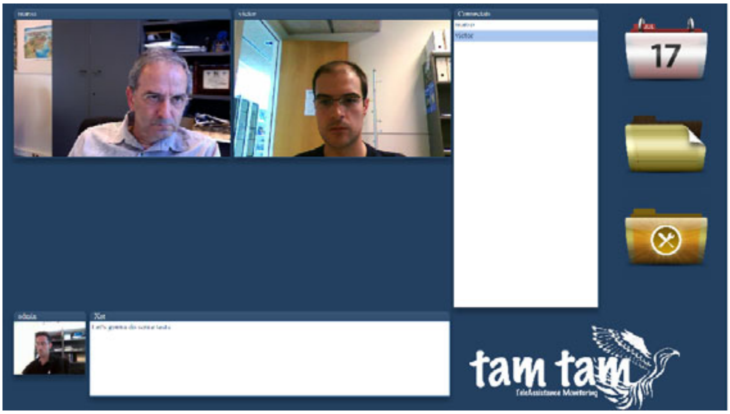

Fig. 3. TAM-TAM application main view screenshot

The control of multimedia flows in Flex is achieved by using the NetConnection and NetStream classes offered by the AS API to create a RTMP/RTMPT connection to the media server and to stream audio and video over that connection. On the other hand, the AS SharedObject class is used for local persistence and for sharing information in real time (e.g. list of connected users with which the user can interact).

Moreover, the possibility of invoking web services from the AS language simplifies the extension of current functionalities and its integration with external services. This has been the approach followed to generate and consult calendar events, notifications and messages, implemented as a PHP web service. The same approach will be used to consult and modify the patient's electronic health record, presumably stored in remote Hospital Information Systems.

3.4 Client Operating Systems and Devices

Since the client application it is to be run on Adobe Flash Player, any operating system and device supporting the Flash technology will be, in principle, suitable for running the client application, as long as it has a microphone, a front webcam and Internet connectivity through fixed, Wi-Fi or mobile Internet access.

Regarding Flash, currently Adobe has specific versions of the Adobe Flash Player for different operating systems: Windows, Mac OS X, Linux, Solaris and Android. For each supported version of those operating systems a list of supported browsers is provided in [13]. As we can see, the use of Flash technology enables the development of applications targeting a very large part of the market, excluding iOS and some old versions of the most common operating systems.

From our experience and tests, we can state that TAM-TAM performs well on all Windows, Linux and Mac, but it still has some limitations when running on Android. Those limitations are mainly related to some security restrictions of Flash web-based applications being run on Android, which are not capable of accessing the local camera for streaming the video or audio. While in other operating systems the Flash player asks the user for permission to access the local camera, in Android this feature is disabled, thus preventing the user to send his stream. However, applications can still receive the audio and video streams from other flash-enabled devices.

Since our goal was to run TAM-TAM on tablet PCs and Android is becoming an important player in this market, the solution adopted to deal with those limitations in Android operating system relies on the use of the Adobe AIR framework. Adobe AIR is a runtime that enables to build standalone client applications without the constraints of a browser. When developing AIR applications for Android, a manifest file needs to be configured for stating which are the local resources the application will have access to, such as the camera, microphone, contacts, etc. Whenever the user installs the air-based android-enabled application, they will be asked to accept the security permissions required by the application, which, form that moment, will be capable of accessing those resources without any further explicit authorization.

3.5 Server Technology

The multimedia server architecture is based on Red5 [14], an open source Flash server written in Java and hosted on Google Code. Red5 supports the delivery of multimedia content through the RTMP or RTMPT/RTMPS protocols, currently owned by Adobe, who has released their specification open for the public use.

The fact that Red5 is an open source project eases the modification of the server and enables the development of cheaper and open solutions with respect to other proprietary server alternatives such as Adobe Flash Media Server and Wowza.

Red5 uses Jetty [15] as HTTP and application server (servlet engine), which can host a custom-made servlet managing the multimedia streams and generating specific events for the connected clients to notify any change produced in the shared objects, and MINA [16], a network application framework which helps users to develop high performance and high scalability network applications. MINA provides an abstract asynchronous API over various transport protocols such as TCP/IP and UDP/IP via Java Non-blocking I/O (NIO). Red5 is available for GNU/Linux, Windows and OSX, which makes it highly versatile to be deployed in different production environments.

The server part also consists of an AMP server, which combines an Apache web server, a MySQL database server and PHP. Whereas the web server hosts the Flash web application for being accessed through the World Wide Web, the MySQL database server is needed for the different databases regarding users, contacts and profiles and the calendar, messages and notifications.

3.6 Technical Parameters and Configuration

As mentioned, any device supporting Adobe Flash will be suitable for running TAM-TAM. For testing, we have used an Acer A500 Iconia tablet PC with Android 3.0 (Honeycomb) operating system. We are also considering the use of Samsung Galaxy Tab 10.1. Basically, those devices have WXGA (1280x800) resolution, high-sensitive capacitive multi-touch screen, front and back camera, mobile and wireless Internet connectivity, Bluetooth and high-performance NVIDIA Tegra 2 processor or similar.

Regarding videoconferencing, in the current version we have manually configured the client's transmission parameters. The upload **bandwidth** has been limited to 48 Kbps to obtain a good performance of the application in limited bandwidth environments, such as crowded wireless and broadband mobile networks. However, it can be configured to higher values in environments with better bandwidth restrictions. When fixing bandwidth, Adobe Flash automatically adjusts any other parameter (except resolution, which is kept static) to fit the bandwidth requirements. The **resolution** has been set to 768x480 pixels, whenever the local camera supports this panoramic resolution. This resolution ensures an appropriate visualization of the interlocutor in 1-to-1 conversations in terms of image size w.r.t the display size in WXGA resolution devices. The video **quality** has been set to automatically fit bandwidth requirements. However, quality can be also configured manually by adjusting the following parameters: image compression, frame rate and the rate of complete video frames that will be used for the video interpolation.

The server that hosts the Red5 server and AMP server is a desktop PC with a Core 2 Duo processor and 4 GB DDR2 RAM running Ubuntu 11 OS. Regarding bandwidth, according to the 48 Kbps limit set in the client's side, when dealing with multi videoconferencing of N users, the server needs to support a N*48Kbps incoming bandwidth plus a N*(N-1)*48Kbps outgoing bandwidth, since video streams are replicated from the server to any connected client.

4 Conclusions and Future work

In this paper we have presented TAM-TAM functionalities, architecture and underlying technology. TAM-TAM combines the Adobe Flex framework, which enables the design of usable interfaces and provides videoconferencing support, with the versatility of tablet PCs, opening the door to the development of portable health applications directed to the elderly, impaired and long-term care patients.

TAM-TAM is currently accessible tool available for demonstration at [17] under the demo section, for which a guest account needs to be requested.

TAM-TAM is developed, as mentioned, in collaboration with the “ICT, socialization and active ageing” working group depending on the Girona's Council. This collaboration relies not only in the collection of the requirements from end users but also in thorough testing with real users in a real environment, which includes nursing and group homes as well as particular homes involving the target collectives. Currently, we have started small-scale tests with selected users who are running standard PCs in their homes. The results are being taken into account for improving the usability of the TAM-TAM application. In the next months, we plan to extend the tests in order to demonstrate the capabilities and feasibility of the proposed tablet PCs. Apart from the planned tests with users, additional non-functional tests and measurements need to be carried out, including server performance and scalability, quality of service depending on the type of connectivity (WiFi, mobile, etc.).

Other relevant features that will be adopted in the future include audio and video recording for keeping track of the patient's evolution, taking pictures of the patient's aspect or some types of lesions, defining user profiles so that functionalities can be restricted depending on the type of user being logged into the system (e.g. health professional, social professional, familiar or patient) and adopting more secure authentication mechanisms, mainly when dealing with health professionals, through the use of X.509 digital certificates. We also foresee the integration of TAM-TAM with external Hospital Information Systems (HIS), so that health professionals (e.g. physicians and psychologists) have access to the patient's electronic health record. This feature enables a better assessment and decision-taking for the professionals and eases the addition of new episodes trough a unique an integrated interface.

Finally, we also plan to include networks analysis tools for dynamically adapting the transmission quality to the available bandwidth and to generate and test an iOS-enabled version of TAM-TAM making use of the Adobe AIR framework.

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Survey Model of the Information Behavior Seeking in the Web for People with Visual Impairment

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Abstract. This article presents a study on the use of the Internet for People with Visual Impairment (PVI). The objective is to consider a model of survey of the behavior of search and use of the information in the Web for PVI through the identification of motivators for the process of search, factors that influence in the interface between the PVI and the contents in the Internet and elements for the identification of the standardized access. The used method was the revision of literature with focus in the studies of the Behavior in the information seeking (James Krikelas), Process of information seeking (Carol C. Kuhlthau) and of the Informational Behavior (Tone D. Wilson). The validation of the considered model was by means of the accomplishment of an exploratory research through interviews with blind people that it made possible to collect the opinions and experiences of these Web users and to identify barriers of access and good practices. As a result, this work considered a model of survey with composed systemic vision for necessities/motivators and intervening factors (Inputs), the way the user processes the information (processing), and the answers, action and reactions front to the accessed information (outputs), based in the concepts of Universal Access and Accessibility.

Keywords: WEB; Visual Impaired, searches.

1 Introduction

The advance of the means of communication and the impact of the Technologies of Information and Communication (ICTs) have influenced the routine of the population, demanding more and more the domain of the computer and its resources in the personal and professional environment. In addition, it has also enabled the access of information and services for the People with Visual Impairment in a way that was hard to imagine before.

It is perceived that with the evolution of screen reading software and the incorporated criteria of accessibility to the Web services, the inclusion of the PVI in the digital universe has became possible. However, there are still problems in the identification of the effective capacity of the resources and contents of the Internet accessibility to the PVI, mainly the new services available in the Web, such as:

M.M. Cruz-Cunha et al. (Eds.): CENTERIS 2011, Part III, CCIS 221, pp. 21–29, 2011.

purchases in virtual stores, digital book reading, navigation in social networks, public information and many other services. The basic question, in this research, appears from these arguments; trying to understand up to what point the Internet is part of the daily life of the PVI with the focus in the search of the information.

Salazar comments that the behavior process in search of information appears from the necessity for information [1. This is considered as the basic element that takes a person to a search for information. One understands that all the process of search of the information starts from a Mechanism of Activation. It is an element that stimulates the user in this way, in this case the PVI. Everything is initiated by the necessity of the information, which, if comprehended, will answer the reason of the use. [2].

Based in this scenario, this research has the objective to offer a model of survey of the behavior of use of the information for PVIs. The adopted method will be of literature revision, where key aspects have been identified. These aspects will help to define the requirements for evaluation of the accessibility of the available resources in the Internet. The aim of this model is to evaluate the accessibility based on the PVIs own impressions. The model was validated from the application of structuralized interviews. The results point with respect to the identification of information on the causes for the access to the Web and the behavior of use and the positive and negative points of accessibility. It is concluded that the considered model gets basic requirements for the evaluation of the available resources in the Internet, thus making possible the development of strategies and effective possibilities of applications for this public access, based in the user's centered approach.

This article is structuralized from this Introduction, the Insertion of the PVIs in the Web, the Proposal of a Survey Model of the Information Behavior Seeking and the Final Considerations.

2 The Insertion of the PVIs in the Web

The technological advances experienced by humankind after the second half of century XX brought deep changes in their daily life. It was intensified, overall during the decade of 1990, in which the computer left the professional environment and started to incorporate homes as indispensable electronic equipment. Since then, information access started to be more and more intense and digital, giving way for the concept of the Information Society, that according to Carvalho & Kanisky [3] is characterized by the intensive use of ICTs. Its use enables the access to the most varied contents through the Internet.

Digital information is available, in its majority, by digital repositories shared in the Internet. Journalistic news, governmental contents (Electronic Government), banking services, e-commerce and social networks are widely available bringing thus innumerable benefits under the view of the access to its contents and social interaction. To live aside this universe results in being excluded from a gamma of indispensable resources in the Society of the Information. This can be caused by the little affinity with the technologies, or by barriers generated for the proper digital universe. This type of alienation to the virtual universe intermediated by the ICTs is called Digital Exclusion [4].

For People with Special Needs (PWSN), the ICTs have opened space for its inclusion with information and services not or little accessible by the traditional ways. It allowed the "(...) possibilities of virtual environments to be assumed as resources for the development, the interaction and the social /digital inclusion of people with special educative needs." [5]. According to the authors, the ICTs are potential instruments to: i) accessibility, through the Internet, to banking services, purchases of products and services, reading of periodicals and magazines, etc; II) the possibility of exchange experiences between PWSN, stimulating and consolidating the social group and its interests; II) the capacity of conversion of auditory visual stimulations / in touch, through software of screen reading and printers in Braille.

Although the existing discourse in the literature regarding the person with visual deficiency and its insertion in the society through the lines of the digital inclusion, social inclusion and accessibility, there is little consistency in the studies focused in the behavior use of the information. Fernanda Schweitzer [4], in its study of case, tells on this lack in the scientific production, and on this critical perspective the present research is supported.

2.1 The Question of the Accessibility

Mazzoni [6] states that with the dissemination of the Internet, new technological supports have appeared, allowing that the users have access to information not reached before, such as electronic magnifying glasses, voice synthesizers and printers in Braille.

In the information society, supported predominant by the ICTs, inclusion measures of the PWSN have been developed in computing studies, being one of the most recognized the world-wide W3C (Consortium World Wide Web) where organized standards of accessibility based on criteria to be fulfilled in a Web page and defined that:

The expression `accessibility', present in several areas of activity has also in computer science an important meaning. It represents for the user the right to not only have access to the net of information, but also the right of the elimination of architectural barriers, availability of communication, physical access, equipment and adjusted programs, content and presentation of the information in alternative formats [7].

Under the point of view of Carvalho [8], it brings the concept of Accessibility incorporated into a systemic vision, understanding the term in question as the process/processing necessary to take the content desired until its user, being overcoming the diverse forms of existing barriers in the digital environment. According to author, the existing barriers can be classified as:

Barrier of Acceptance: they indicate difficulties referring to the culture of the individual or their affinity with the technology;

Barrier of Communication: it is in respect to the difficulty or impossibility of the dialog between the user and the deriving digital resources of the inadequate use of languages both human and computational;

Barrier of Access: referring to the difficulties of the user in arriving to the source of the desired information;

Barrier of the Learning: problems in the interpretation of the accessed contents.

These barriers pointed by Carvalho [8] are part of the model considered in this research.

Another point to observe is how much the available resources in virtual environments (virtual laboratories) related to distance learning that can be used by PVIs. To rethink a way to integrate the formation of the conventional model associating the new technologies applied to the access to the PVIs, can become a resource in the education process learning [9].

3 The Proposal of a Survey Model of the Information Behavior Seeking

It is perceived that the studies regarding the Information behaviors seeking have been widely developed from the change of paradigm in middle of the decade of 1980. The current paradigm guided for the system is collated, appearing the paradigm guided for the user (Systems Centered in the Users) [2, 10].

The alteration of the focus for the user in the Web development process applications brought a set of knowledge of Cognitive Studies and Information Science, in the construction of the foundations for the survey requirements from the behavior seeking of contents.

The process of information search is set the moment the user identifies a specific necessity. The identification of the necessity by the individual entails the Mechanism of Activation, and its agreement answers the reason of the search [11, 1, 12, 13, 14]. The lack of identification of this necessity results in the non accomplishment of the search process.

For People with Visual Impairment (PVIs), the use of screen reader system gives basic resources for the search, and acts as Interfaces between the user and the Internet. These systems translate visual stimulations into auditory, and depend on the adequacy of the resources of the Internet to be suitable, so that it is possible the accomplishment of the process [8].

During the entire Interface, external and internal factors of the individual intervene in a positive or negative way [15, 16, 17], and affect directly or indirectly in the perception of the user on the relations of risks and rewards [2, 11]. The Motivators are those whose interferences are positive, and extend the notion of reward for the user. On the other hand, the Barriers are the elements that act in a negative way for the user, intensifying its perception of risk in the process [18, 19, 9].

The composed set by the Mechanisms of Activation and the elements of the Interface affect the Use of the Information. It represents the concretization of the relation Rewards/Risks in the process and the capacity of translation of the contents for the Screen Reader System, and they are composed of 4 aspects:

When: referring to the intensity and frequency of use of the information in the Internet;

What: it represents the sources of information accessed by the user;

Where: referring to the places the user is capable to access the Internet.

Figure 1 shows a graphical representation of the considered model.

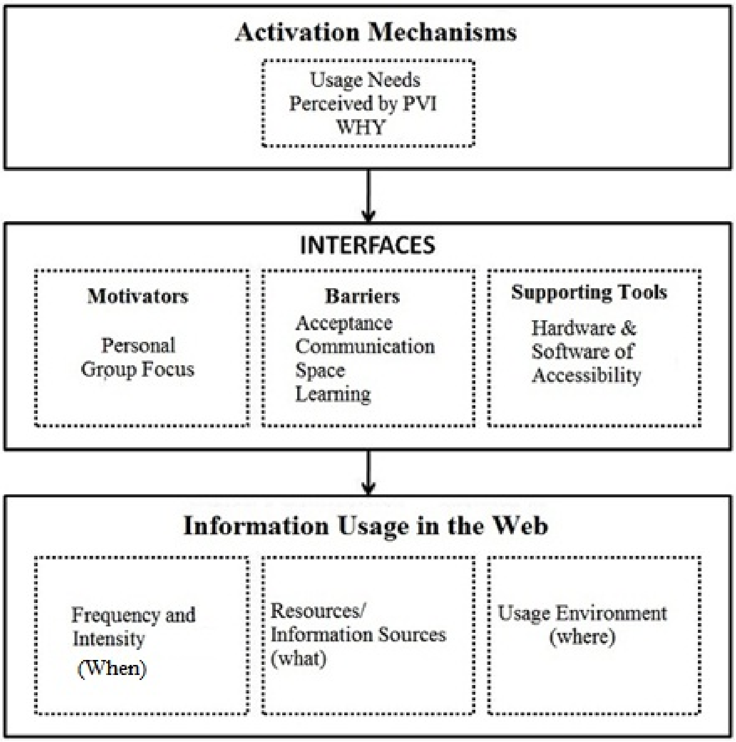

Fig. 1. Model of survey of the behavior of use of the information in the Web for people with visual impairment

All the items presented in figure 1 show a vision of the process under the equation form. The Use of the Information (U) is the result of the relation between Motivators (M) and Barriers (B) perceived by the user, raised to the power by the capacity of the Screen Reader System (S) used in interpreting the contents of the Web and stimulated by the Mechanisms of Activation (A).

$$U = A * (S * (M – B))$$

Once the Mechanisms of Activation are those responsible for the identification of the necessity of the search for the user, its inexistence (value = 0) consists of the non use of the information, as well as the incapacity of the Screen Reader System in decoding the contents (value = 0) also implies in not the effectivation of the process. The values of the indicators are obtained from a questionnaire composed of multiple choice answers. There are five options for each question, which will define a percentage to the variables (0%, 25%, 50%, 75% or 100%). For a more detailed analysis, the variables are available to each content category. Thus the researcher is able to identify which content is easily accessible, and which one needs adequacy.

3.1 Validation of the Model

This model of survey is focused on blind PVIs, whose perception of visual stimulations is inexistent, and was validated from random research of qualitative character in individuals of one same region. All the investigated ones in the validation had a computer and access to the Internet in their houses, making those relative barriers to the non access to the ICTs generated interferences in the research.

As an instrument of data collection, a half-structuralized, composed questionnaire was elaborated with 16 open and closed questions, grouped by investigative aspects (Mechanisms of Activation, Interface and Use of the Information). The application of the questionnaires was carried through by interviews previously set appointments, leaving the opened PVI to display their experiences and impressions on the diverse available contents in the Web (websites, systems of communication in real time, social networks, and electronic commerce, banking services and information sites /governmental services).

Table 1 reveals the main results of the research in the verification of the considered model. The results of the research here will not be presented in a whole, due to its extension and the available space, but it made possible an important validation for the survey model:

The observations of the Mechanisms of Activation are essential in the process of search of the information, once all the PVIs interviewed had access exclusively to the contents that they judged excellent. In many cases, available resources such as websites of audio and digital books were of knowledge of this group; however they did not use them for considering unnecessary even before trying such resources.

The identification of Barriers and Motivators were innumerable, varied, and related with categories of contents in the Web, demonstrating that the Motivators - Barriers relations are crucial for the effective use of the information. The Systems of Screen Reading was presented as a determinative points for the possibility of the content use.

The Use of the Information is related directly with the Mechanisms of Activation and Interfaces, reflecting over all in the intensity and frequency of use (When). The used sources of information (What) and the accessed places (Where) indicated the amplitude of use of the resources of the Internet by the PVIs.

The use of this model of survey was satisfactory, representing in simplified and efficient way an including vision it behavior of search and use of the information by the PVIs. However, being a model that embarks multiples analysis aspects, its use is not recommended for inquiries of small amplitude and high depth, whose approach search to answer the exclusive elements of the behavior of the users.

It is perceived researches directed to the evaluation of accessibility to resources in the Web aiming at the availability of the resources following the norms proposal for accessibility. However in this proposal, the evaluation was of the use of the available and accessible resources for the PVIs, as presented in the summary of the results gotten in Table 1.

Table 1. Main results and considerations acquired in the survey of the validation of the model of investigation

Investigative Aspect	Main Results	Considerations
Information Sources/ Resources (What)	83% of the PVIs access systems of instant messages daily, only 17% check news sites or read news feeds weekly, 16% do online shopping and none of the interviewed uses online banking services.	Predominance of the Internet as direct communication channel between PVI and other people, having reduced use as source of information and channel of offers of services.
Frequency and Intensity (when)	Daily average use of the Internet of 9:10 h, with bigger intensity during the end-of-the-week.	Use of the Internet in an intense way on free schedules.
Access places (where)	67% of the PVIs use the Internet at home and in the work environment, and none of the interviewed uses mobile technologies such as *Smartphones*.	The PVI consider important the access to the *Web,* however they haven't had a chance to try the mobile technology.
Activation Machanisms (why)	84% use it to communicate with other people, while 57% have access to get information of professional matter/*hobbies*.	Although initial interest of 57% of the PVIs in getting information in the *Web*, the use for this objective is low.
Motivators	8% of the PVIs point the mechanisms of search in the *Web* as important tools to find the contents desired, and 33% consider the notebook as an important resource for mobility in the use of the Internet.	The existence of mechanisms that facilitate the search of contents through words are basic points to facilitate its use.
Barriers	85% point the accessibility of the pages and services in the Internet as the main difficulty of access.	Extreme number of links delay the access and inaccessible multimedia contents diminish the motivation
Screen Read System	90% of the PVIs consider that these systems need more practical functionalities and 57% feel the necessity of advances with regard to translation of multilingual texts.	These systems are central for their users; however they require mechanisms of artificial intelligence for identification of the language used in stretches of text and to adjust its mechanism of translation from text to voice.

4 Final Considerations

The article made possible the organization of theories of the behavior of search and use of the information in an applicable model of survey for the comprehension of relevant requirements for the available resources in the Web toward the PVIs. The comprehension in the way of how they use the information in the Internet makes possible the planning of new strategies of accessibility that allow the inclusion of this public in the digital environment.

The main motivator for the navigation in the Web was verified that, is the necessity of PVI' s in communicating with other people, either to extend their net of relationship, or to keep in touch with friends that are distant. The search for information of personal or professional interest has also been excellent in the activation of the process of use of the Internet. In relation to the use behavior, the Internet is used constantly and for several hours daily, either during the week or end-of-the week. The use of tools of searches in the Web is unanimous and of great importance for localization of contents. Amongst the sources of information strong used by these users are pages directed toward blind people or with subnormal vision, and as little used the websites. Online banking institutions had been never used by the participants of the research.

The use of communication tools was evidenced as systems of instant messaging; systems of conversational way-voice and the email are effectively the most used methods. The computers are always adapted for navigation in the Web, either in their residences, or in another environment. One perceived that the main Intervening Factors while Motivator is the possibility to talk with other people way-voice, and while Barrier is the accessibility of the pages of Internet which was perceived the limitation of access of the interface between the page and the SLT, as well as of the architecture of the information (texts and hyperlinks).

Thus, this research brought for the discussion the importance of the inclusion to the contents in the Web to PVIs, therefore the Internet is an important mean of access to the information and of communication, and has a still bigger potential. However, this depends that the accessibility speech is not restricted to the field of the computation, but allied with proper aspects of the user in the use of the information and the adequacy of the contents.

Future works can be indicated from this research, in the way of the development of models of survey for other groups of special people with necessities, such as the deaf people. Also the application of the model presented here in an ampler sampling is proposal, bringing a variety of requirements for contents in the Web for academic discussion.

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Investigating the Use of Visualisations of Biomechanics in Physical Rehabilitation

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Abstract. Biomechanical analysis can be used to scientifically assess the causes of movement problems, measure progress and validate outcomes. However, the complexity of the data produced and the training required to use the available biomechanical analysis tools prevents the widespread understanding of this form of analysis beyond those with a background in biomechanics. This paper reports on multidisciplinary research, funded by the MRC's LLHW programme, into the generation of three-dimensional, dynamic visualisations of biomechanical data and investigation of their use during functional rehabilitation trials, e.g., post-stroke, knee-joint replacement, and older adult exercise. The research will test the hypothesis that increased understanding of biomechanical concepts and measurements through this method of visualisation by both patients and clinicians will result in better patient outcomes.

Keywords: Visualisation, Biomechanics, Rehabilitation.

1 Introduction

Biomechanical analysis can be used to scientifically assess the causes of movement problems and to measure rehabilitation progress and outcomes. However, at present biomechanics is only explicitly used in a small number of specialist rehabilitation scenarios. This paper reports on multidisciplinary research investigating the use of visualisation software to enable the application of biomechanical data and analysis in a wider range of rehabilitation settings.

The paper begins with a discussion of the benefits which biomechanical analysis can provide for rehabilitation, and the factors which currently limit its widespread use. The approach taken in the research to overcoming these limitations is then introduced: firstly, the potential for visualisation techniques to communicate complex, dynamic biomechanical data in an accessible way to those without biomechanics training; secondly, the investigation of the application of the visualisation software to five different rehabilitation scenarios, which cover a range of different rehabilitation settings and complexity of patient condition. In the last section, the implications of the different rehabilitation settings are discussed: hospital, community and home.

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2 Biomechanics in Rehabilitation: Current Limitations and Potential Benefits

The aim of physical rehabilitation is to work the musculoskeletal system in the most effective way to restore function and quality of life following injury or illness e.g. to rebuild soft tissue which has been damaged or underused; or enable relearning of motor control of muscles following brain injury.

Rehabilitation professionals therefore need to (a) assess the difficulties the patient is having with movement, and (b) determine and discuss with the patient realistic rehabilitation goals, and a programme of rehabilitation tasks which could restore their function to meet those targets.

Human movement is complex and dynamic. If you ask several people to perform the same functional task, each will achieve it by moving their body in a different way – these differences are often subtle and therefore difficult to see by eye. Biomechanics can provide highly accurate data on human movement beyond the immediately observable. However, to date biomechanical data measurement and analysis have only been used in a small number of rehabilitation scenarios. The most common clinical application for biomechanics is in gait analysis. Due to current biomechanical analysis systems, these are specialist sessions which are expensive both in terms of the equipment required and the number of staff needed to collect and interpret the results.

The following sections describe the limitations of current biomechanical analysis systems and software, and the potential benefits which could be provided for patients if these limitations could be overcome.

2.1 Limiting Factors to Widespread Use of Biomechanics in Rehabilitation

The biomechanical analysis systems currently available are highly accurate, and provide dedicated software to analyse the kinematic and kinetic parameters of movement. While the tools offer flexibility for specialists, there are a number of limitations to the systems which make them unsuitable for general clinical use.

- The analysis software is tightly integrated with expensive laboratory equipment limiting its use to only a small number of hospital facilities. The majority of therapists in the UK rarely have access to motion analysis equipment [1].
- Most therapists do not have training in biomechanics to the level required to collect motion analysis data and then use the software to perform an analysis.
- Interpretation of the data collected by motion analysis, particularly with clinical gait data, is also considered to be problematic [2]. *"Interpretation of biomechanical data is complex, time consuming and not readily understood by most therapists"* [3].
- Biomechanical analysis tools are designed to be general purpose, and are not tied to any particular rehabilitation application. This is beneficial in terms of the flexibility of the tools. However as a result, they provide all the data measurements from a motion without any guidance on which parameters are important or how they relate to each other.

- The representations of biomechanical analyses of movement in current tools are of limited use when trying to communicate to those without a background in biomechanics – with other health professionals or the patient themselves. This is generally presented in the form of a generic 'gait report' which is thought to contain too many pages of text, graphs and figures [4].

2.2 Potential Benefits of Biomechanical Analysis for Rehabilitation

There are a number of potential benefits to the use of biomechanical analysis in rehabilitation settings. Motion analysis systems and supporting software enable the collection of accurate, repeatable and objective data on the complex dynamic movements patients perform. This type of analysis has shown a demonstrable positive effect on clinical decision-making in the context of gait analysis [5, 6]. The ability to provide this data in other rehabilitation settings could enable clinicians to make more informed decisions.

While biomechanical analysis in rehabilitation can be beneficial to clinicians, it may also prove advantageous to patients as it could assist them with understanding their rehabilitation tasks, goals and progress.

The benefits of involving patients in their own care have been demonstrated [7, 8]. Patient understanding of their treatment and effective communication with clinicians have both been identified as having a positive impact on their compliance [9] which leads to a better chance of improved treatment outcomes [10].

Understanding plays a particularly important role in stroke rehabilitation. In one study, stroke patients identified as highly motivated stated that information from clinicians helped them to understand their goals, identify progress and take an active role in their own rehabilitation. Lack of understanding on the other hand was thought to contribute to non-compliance. Furthermore, the ability to discuss, or even challenge, the decisions with clinicians was described as important [11].

3 Visualisations of Biomechanics: Applying Biomechanics to Specific Rehabilitation Scenarios

The field of Information Visualisation offers a potential route to improving the communication of the complex and interrelated biomechanical parameters describing human movement. Visualisation uses visual representations and interaction techniques to use the processing power of the human eye to enable people to see, explore, and understand large amounts of information at once [12]. Further, it goes beyond simple presentation of data, but rather enables understanding the meaning of the data, or even has the ability to create new meaning which was not visible before [13]. Visualisation can provide new insights about data, supporting discovery, decision making and explanation [14].

In previous work by the authors [15, 16] the ability of visualisation techniques to communicate biomechanical data on the demands of activities of daily living for older adults were investigated. The research aimed to improve on the traditional approaches of using static graphs, tables and figures by producing three-dimensional, dynamic visualisations of biomechanical data. The research found that through the use of visualisation techniques the biomechanical data, which would usually have been inaccessible, could be understood by both lay and professional audiences. Further, the visualisations were shown to enable new cross-disciplinary dialogues about the data between the professionals and lay members.

While this research proved the potential value of visualisation to communicate biomechanical data to a wider audience, the data did not directly benefit the individual that was measured, so could not be fed back to the patient to help them to correct their movements or suggest exercises to improve their functional capability.

The **en**vis**age** project, funded by the Lifelong Health and Wellbeing (LLHW2) initiative, will investigate the potential of visualisation software to address the challenges of using biomechanical data in rehabilitation. The project is a multidisciplinary collaboration between the University of Strathclyde, The Glasgow School of Art and Glasgow Caledonian University.

Five discrete work packages have been selected to investigate the use of visualisations of biomechanical data in a range of rehabilitation settings, involving different treatment processes and complexity of condition.

- Falls prevention advice and visual feedback to those at risk of falling. (Home-based)
- Functional exercises for the rehabilitation of total knee replacement patients. (Home-based)
- Lower limb stroke rehabilitation for acute stroke patients. (Community-based)
- Upper limb stroke rehabilitation for acute stroke patients. (Community-based)
- Diagnosis and fitting of an ankle-foot orthosis in late stage stroke. (Hospital-based)

Each work package will evaluate the effectiveness of the visualisation software intervention on patient outcomes in a Phase II randomised clinical trial (exploratory) as defined by the MRC and will follow MRC guidelines for the evaluation of complex interventions [17].

To complement the quantitative outcome measures from the trials, qualitative data will be captured before, during and after the trial. This is essential for a complex intervention, in order to understand the determining factors in the quantitative outcome measures from the trial [18]. The qualitative research will explore the effects of the use of the tool on the experiences and understanding of both the patients and therapists separately, as well as the effect on the interactions between the different participants.

4 Designing Biomechanical Visualisations: Addressing the Requirements of Different Rehabiliation Scenarios

A different visualisation software tool is being developed for each work package to address the five specific clinical rehabilitation scenarios. In order to design the software to be appropriate to each scenario, there are a number of interrelated factors which need to be considered. These factors include:

- the rehabilitation setting
- the motion capture technologies employed
- the specific biomechanical parameters that are important (a) for clinical decision-making (b) to enable patients to better understand their tasks, goals and progress
- the patient's needs and experience of the rehabilitation process

The following sections illustrate some of the implications of these different factors for the design of the visualisations. The factors are discussed in relation to the three rehabilitation settings being investigated in the project - hospital, community and home.

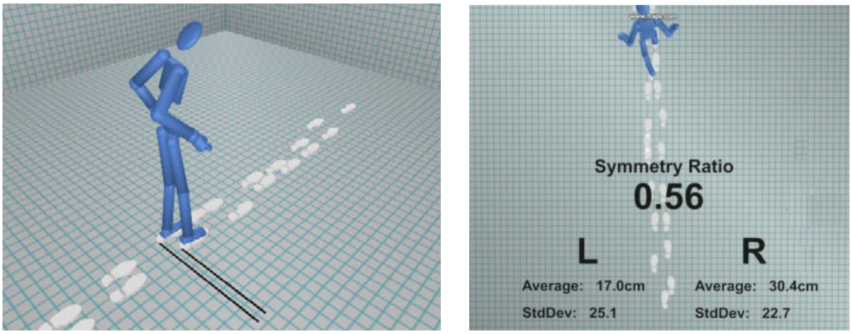
4.1 Biomechanical Visualisation in Hospital Rehabilitation

Technology. In the hospital setting, the conditions to be assessed will be complex, requiring specialist treatment. There will be a fixed, laboratory setup providing full-body optical motion capture and force plate measurements allowing for full kinematic, kinetic and spatiotemporal parameters to be collected. This system requires a high level of training to set up and operate. The system is expensive and not portable, however it does offer a high level of accuracy. An extensive range of biomechanical data are available for the visualisation software in this setting.

Biomechanical Parameters. The parameters of interest at this stage of the patient's rehabilitation will be those that are relevant to re-establishing the patient's functional capability (in contrast to the quality of the movement in the other scenarios).

There will be two different types of visualisation in this scenario: diagnostic, for the therapist; and explanatory, for the patient. The tool will need to be flexible in allowing the therapist to choose what visualisations are appropriate for different patients. Visualisations will be viewed off-line, as in this rehabilitation scenario it is important that the patient walks naturally and without any visual distractions.

For analysis, the visualisation tool needs to assist the therapist to interpret the complex and interrelated data which describe the movement. For example, two key progress measures for lower limb stroke rehabilitation are walking speed and symmetry of gait. The tool will enable the therapist to interactively select and view different biomechanical parameters relating to the outcome measures, to make more informed clinical decisions about the patient's rehabilitation. For communication to the patient, the visualisations will be able to be configured to enable the therapist to explain the various parameters measured, what they mean and how they relate to the patient's progress. In Fig. 1., the effect of step length on walking speed and gait symmetry are displayed in two different ways – the first for communication to the patient, the second for detailed analysis by the therapist.



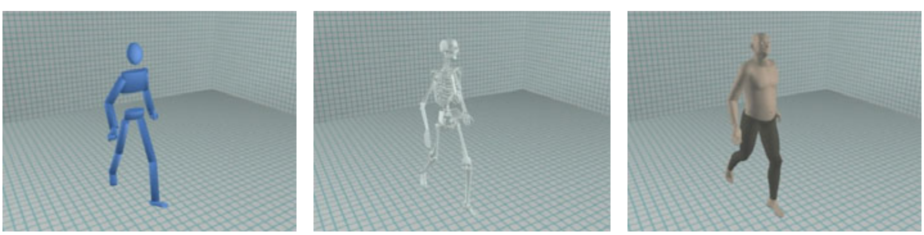
(a) (b)

Fig. 1. (a) Example visualisation which visually shows the relationship between step length, gait symmetry and walking speed (b) Example visualisation which displays the same captured motion data, but provides diagnostic numerical data for the therapist

Patient Experience. Patients attending the rehabilitation sessions will be in the acute phase of their rehabilitation pathway, and will be more reliant on their therapist to lead the rehabilitation process. The patients will also find themselves in an unfamiliar setting.

In the design of the visualisation, sensitivity will be required in the representation of the figure and managing how the patient sees their own movements. For example, in the first session the patient may not have seen the severity of their movement problems in a clear objective way before. In fig. 2, the same movement is shown using different figure representations, each with different potential for an emotional response. The software will enable the representation of the figure to be chosen by the patient.

The patient's progress through their rehabilitation will also require to be sensitively handled. Progress through rehabilitation can be complex. There may be periods of rapid improvement, but also times where improvement is small, or there may be intermediate reductions in capability. The approach taken in the research to this sensitive area will be to make the tool flexible in how progress is communicated to the patient and give the therapist control over when and how progress is communicated. A potential advantage of the visualisation tool in this scenario is that the progress can be communicated by an objective tool, rather than by what may be conceived by the patient as the opinion of the therapist. The benefits this may provide for the interaction between the therapist and the patient will be explored in the research.

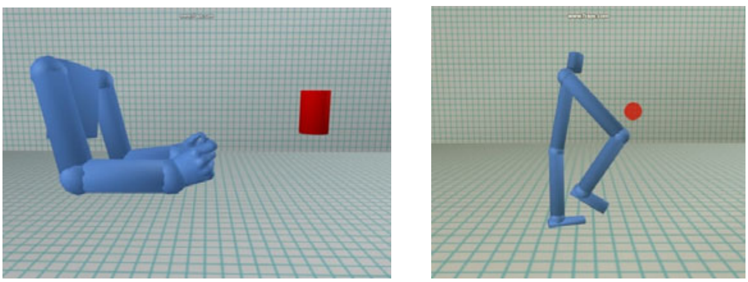


(a) (b) (c)

Fig. 2. (a) Stick Figure representation (b) Skeletal/Anatomical representation (c) Realistic representation

4.2 Biomechanical Visualisation in Community Rehabilitation

Technology. In the community setting, the motion capture technology needs to be portable, and easy to setup and dismantle as they will mostly be used in shared spaces. The system will be setup and operated by the therapist, so this needs to be intuitive and quick to achieve. In order for the system to be feasible, it should be reasonably inexpensive. Low cost optical motion capture will be used for the lower limb stroke rehabilitation, and a wired electromagnetic system will be used for upper limb rehabilitation. Partial body motion capture will be used in this setting to enable quick setup of the equipment – one will capture only upper limb motion, the other only lower limb. This has obvious implications for what can be shown in the visualisation, as can be seen in Fig. 3.



(a) (b)

Fig. 3. Visualisations of partial-body motion capture. In each the participant is trying to reach for a virtual target (a) Upper limb and torso data only (b) Lower limb data only.

Biomechanical Parameters. The data collected and analysed by the therapist will be limited to kinematic and spatiotemporal parameters, and will be interpreted with a focus on quality of movement. There will be a greater emphasis on showing real-time data visualisations so the patient can receive instant feedback of their movements as they perform them. As in the hospital setting, the therapist will be on-hand to explain the visualisations to the patient and use them as a basis for discussion.

The rehabilitation tasks in the community setting are such that there are not necessarily distinct biomechanical goals defined in the literature with respect to the parameters measured. The goals have been determined by researchers engaging practicing therapists in the design process and unearthing the essence of each task.

Patient Experience. The patient will have been considered eligible to go home as part of early supported discharge. Their rehabilitation sessions will still be at regular intervals, and face-to-face with their therapist. The sessions will focus on increasing the quality of the movements rather than achieving functional goals.

The visualisations will focus on providing objective communication of compensatory movements which they may not be aware they are making. The reasons that the compensatory movements are reducing the effectiveness of the task will be visually demonstrated.

4.3 Biomechanical Visualisation in Home Rehabilitation

Technology. The home is not a controlled environment, in contrast to a laboratory setting e.g. the size and layout of the room will vary; there will be different lighting conditions; other people may be present, not just the patient. This implies that the technology used needs to be simple, inexpensive and be able to set up without technical assistance. For this project, we will be using custom-made wearable wireless motion sensors. Feasibly the patients can only be asked to put on a small number of sensors, so that it is not onerous to use. The data on only selected segments of the body will be able to be measured and partial figures visualised. The patient's exercises can be recorded every session, providing many more measurements than can be achieved in e.g. a 1 hour session in a clinical setting.

Biomechanical parameters. The biomechanical parameters for home rehabilitation are very similar to those in the community setting – limited to kinematic and spatiotemporal and focused on quality of movement. They will additionally involve counting the number of repetitions, although the main difference is that there will be no therapist on-hand to explain the results. This means that the software design will need to place a greater emphasis on the pre-prepared explanatory material which explains clearly to the patient the biomechanical goals and objectives of each exercise.

Patient Experience. For home rehabilitation, the patient will be medically stable, and expected to self manage their use of the rehabilitation tool. The use of the tool will be voluntary in contrast to the other settings where the therapist will guide and encourage the patient. As the patient can use the tool to get immediate feedback at any time on their exercise performance and progress, how this is communicated will need to be handled carefully to avoid adversely affecting motivation and adherence.

The interaction with the therapist in the home will be less than in the hospital or the community (for the conditions investigated in this project, the level of contact with therapists is usually low). To address the reduction in patient-therapist interaction there are a number of options. Firstly, one could encapsulate some of the therapists' knowledge within the tool e.g. by creating rule-sets to automatically adjust goals for changes in performance and fatigue. Alternatively, one could establish a facility for regular remote communication with the therapist either live (via webcam/videoconferencing or phone), or offline using email. In conjunction with this, the recorded sensor data could be sent to the therapist to view using the same software tool so that both are looking at the same image.

5 Conclusions

The ability to apply and communicate biomechanical analysis to a wider range of rehabilitation settings than presently possibly could offer many benefits for both therapists and patients.

In order to achieve this, the research will provide visualisation software tools which support the analysis and interpretation of biomechanical data relevant to specific rehabilitation scenarios. The technical and practical limitations for the different rehabilitation settings will be explored in the research, to test the feasibility of the implementation of this approach.

The quantitative outcomes from the randomised controlled trials will test the hypothesis that use of visualisation software to communicate biomechanical concepts and measurements will result in better patient outcomes. Equally important to the study will be the qualitative research before, during and after the trials to explain the quantitative outcome measures i.e. which aspects of the use of the visualisations were successful or otherwise; whether the therapists better understood the biomechanical concepts and measurements, and whether this changed their diagnosis; the effect of the tool on the patient's understanding of their rehabilitation tasks, goals and progress; and any effect on the ability for the patients and therapists to communicate more clearly about the rehabilitation tasks and goals.

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User Identification: A Key Factor for Elderly Viewers to Benefit from Interactive Television Services

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Abstract. The offer of interactive television services is becoming more and more frequent in regular households allowing a more customizable way of watching TV. However, in a multi-viewer environment a truly personalized TV experience could not merely rely on the identification of the STB that users have at their homes. For this purpose, a non-intrusive user identification technique is especially relevant, namely when senior viewers are at stake. In this work we are studying different approaches to perform an adequate identification of senior viewers so they can benefit from a series of interactive services targeted to their needs. To achieve this aim, a set of exploratory interviews have been carried out, and based on its results, a prototype with several identification technologies has been developed. With this prototype and through a set of usability tests we were able to collect relevant opinions about the type of added value TV services that this target audience desires. In addition, it was also possible to understand points of view that lead us to conclude that the user context involves a complex trade-off that influences the choice of the most suitable identification system.

Keywords: User Centered Design, iTV, Elderly, Viewer Identification, Privacy.

1 Introduction

Watching TV is a daily activity for most of the human beings. In recent years, with the advent of new TV broadcast systems such as Digital Terrestrial Television (DTT) and IPTV (Internet Protocol Television), this activity is changing [1]. Some of these broadcast systems introduced a return channel which has the potential to provide a high level of content personalization. In this technological scenario, the multiplicity of interactive TV (iTV) services faces a constant increase. However these enhancements, as the services are supported on STBs used by multiple unidentified viewers, the experience lacks in terms of personalization being not completely adjusted to the viewer. This limitation can be overcome if the TV provider knows who is really watching TV, then being able to offer interactive services more suitable to the

M.M. Cruz-Cunha et al. (Eds.): CENTERIS 2011, Part III, CCIS 221, pp. 40–48, 2011.

viewers' profile, such as: personalized ads, automatic tune of favourite channels, automatically adjusted audio description, health care or communication assistance. To accomplish this it is of paramount importance to improve the TV provider infrastructure with a reliable Viewer Identification System (VIS). In the particular context of this work, we are special interested in the development of a VIS targeted to senior viewers, thus it is important to understand their needs and motivations when in front of the TV set. The interest on this target audience comes from the actual worldwide scenario where the number of older persons is increasing as confirmed by the World Health Organization (W.H.O.) that reports an increasing rate of 2,7% per year in the group of people having more than 65 years (with a prediction of 2 billion people in this group in 2050) [13]. This trend justifies a careful consideration of the needs and characteristics of this target group when developing appliances and services to their homes.

2 Related Work

Personal identification is actually needed for varied sectors such as ICT, banking, border control or law enforcement. They rely, at least, in something that people carry, in something that people know or in some physical characteristic of people. In recent years, based in these concepts, several methods to perform TV viewers' identification have been proposed. The following examples intended to illustrate a few of these methods and to refer some of the academic work in the area:

1. RFID (Radio-Frequency IDentification) tags [6, 2];
2. image processing systems [5, 11];
3. smart cards [15];
4. inferring identity using accelerometers in TV remote controls [3];
5. Java Card with user's identity data [15].

The first system relies on RFID tags that the viewer has to use in order to be identified by the iTV service that stores the information concerning the viewer preferences. In the second method, imaging processing algorithms are used to recognize the face of the viewer. This technique implies a large processing power on the STB or, in alternative, additional hardware to do local or remotely image processing. These systems are highly dependent on light, face position and processing time. The use of smart cards to identify users is similar to the method based on RFID tags; however, the user information is stored in the card. This emphasizes the problems related with card loss because the data about the user are stored in the smart card. Nevertheless, the use of a smart card reduces the information stored in the iTV application servers, thus minimizing privacy issues. In the fourth example a system that identifies the viewer through his way of handling the remote control (using accelerometers) is proposed. According to the authors this identification method is non-intrusive and quite comfortable to the viewer. In the last method, the TV viewer has a Java Card in his mobile device and the platform uses it to grant viewer's data and offer personalized content. This system is supported mainly in a Java Card based Universal Subscriber Identity Module (USIM) applet that is responsible for the mobile communication and for managing user's identities. Taking in consideration these and other viewer identification solutions, in the scope of this work we aimed to understand which is the most suitable to be used by elderly. In this context, the result of this work can be characterized in the field of Gerontechnology because it aims to fulfill a technical need of an aging society [4]. Gerontechnology "is technology in direct contact with insights into ambitions and needs of aging people in their environment and the aging process itself" [4]. Technologies developed in this research area intend to ensure good health, active social participation and independent living. As referred by Harrington [4], it is important in this context to understand specific characteristics of this type of users. Some of these will be discussed in the next section.

3 Target Audience

When trying to define elderly, it can be said that for most of the developed countries, people that have more than 65 years are considered old, although this is not the case in African countries where life expectation is less than most of other countries. There are however other definitions but the older age is normally related to the possibility to receive retirement benefits.

"At the moment, there is no United Nations (UN) standard numerical criterion, but the UN agreed cutoff is 60+ years to refer to the older population." [12].

Despite these "calendar based" definitions, Luisa Lima [10] depicts that, on average, people consider itself older when they have more than 62 years. This statement is supported by a study considering the mean values of 28 countries. Figure 1 shows the results of the study and depicts that as far as people get older, they tend to lengthen this threshold age.

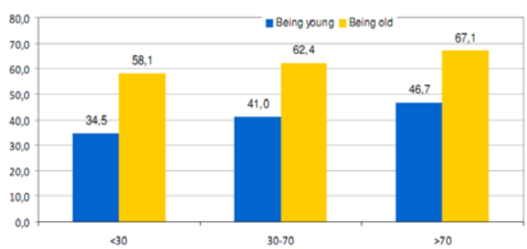

Fig. 1. When does old age begin? [10]

Specifically in Portugal, people think that, on average, youth ends at 35 and old age begins at 65,6 [10]. This result enforces that the definition of older person is not only based on a number but several other cultural effects should be considered. We decided to focus our work in people with more than 55 years old. As time passes and people get older, some important changes occur at physical and psychological level. Elder people tend to have difficulties to adapt to new environments and usually feel lonely [7]. Along with this, elders spend a significant amount of time watching TV motivated by feelings of relaxation, entertainment, companionship, information utility, escape to social interaction and leisure [7]. As mentioned, elderly is also often associated to the retirement period. [4]. However, life expectancy is increasing all over the world, reflecting in a longer period where retired persons guaranty a high level of their quality of life. This situation is often related to a set of activities and goals that keep elders physically and mentally active, pushing the life expectancy further. Gerontechnologies can also play an important role to push life expectancy further by stimulating civic participation (political movements, charity activities and others), physical activities, and cognitive exercises. Thus, considering that elders spend a remarkable time watching TV, that they are comfortable using it due to the maturity of technology and tend to have a relaxed and prolific life, there are multiple advantages in the development of Gerontechnologies supported on interactive TV systems.

4 Identifying Elderly Users

Each person/environment set is unique and encloses specificities that are complicated to address in system's design. Taking this into account, we defined a research process hoping that we would find a suitable viewer identification system for interactive TV services.

4.1 Research Process

Developing a technology in the gerontechnology domain is not a "straight forward" process [4] and implies several interactions and iterations. We defined a research process (table 1) with a first set of five exploratory interviews to help in the system design. The experience gathered from this first contact also helped us to tune the interviewing style. Taking in consideration the sociological and technical literature review and the data collected on this first phase, a prototype (explained later) was developed to support the following round of interviews/tests. The second phase was based in nine interviews to gather opinions concerning the different identification processes presented in the prototype.

Table 1. Interviews' characterization

Heading level	Phase I exploratory interviews	Phase II –Interviews and tests
Nº of interviews	5	9
Aim	- adequate interviewing style; - get a better knowledge about target users; - gather some opinions about the most suitable technology to identify elderly viewers in iTV platforms;	- compare and get opinions on different interactive TV identification systems;
Method	Interviews were made using an interview guide as support;	Interviews were made using an interview guide as support, and test were made using a prototype

4.1.1 Exploratory Interviews – Phase I

Elderly are a highly heterogeneous group that lives in multifaceted environments influenced by several social structures that builds the way that they face life. Due to this heterogeneity we decided to use a general interview guide approach to ensure that the same ideas are collected from interviewees. This approach allowed a degree of freedom and adaptability in the interviewing process that was important to create a more relaxed and enthusiastic environment in the interviews [8]. To the exploratory interviews we selected the participants, randomly, using the list of inhabitants from Anadia, a small size Portuguese city. In order to assure a relaxed environment in the interviews a preliminary phone call to each interviewee explaining the process and the motivations of the work was made; and all the interviews were carried at elders' houses. In this group, the estimated time spent viewing television was three and a half hours per day. We could verify that people of this set:

- do not use computers and internet often;
- TV watching is their main occupation;
- generally, don't like to speak about technological gadgets;
- have difficulties in conceiving scenarios related with new possibilities of technological enhancements;
- most of them are concerned about healthy issues and agree on the advantages of an iTV service in this field.

Concerning iTV viewer identification, we described (using a common sense language) a set of options to the interviewees:

- RFID card (a card that should be passed near a reader);
- Fingerprint reader in remote control;
- PIN code;
- Voice recognition;
- RFID bracelet (a bracelet with an identifier);
- Mobile phone with Bluetooth activated;
- Face recognition;
- Remote control with a gyroscope to make handling recognition.

These interviews (phase I) revealed that without a prototype it turns difficult to seniors clearly identify the advantages of an automatic identification system in iTV context. Due to this constraint, they tended to disperse their answers: Fingerprint reader and RFID card each got one vote and face recognition two. The other methods did not get votes. However, three of the five interviewees referred the need to be able to turn-off this system anytime they want. All valued the importance of a system that can be used to help them in daily living events and to help their caregivers' network. It is worth to say that to two of them even before being asked spontaneously mentioned this importance. After these interviews we strengthen the need to develop a prototype to clearly explain the identification methods.

4.1.2 MedControl Prototype

In order to present the users with a layer of services that benefit from the viewer identification methods, the prototype was built on top of the medControl service. This module is a medical reminder developed under the research project iNeighbour TV (PTDC/CCI-COM/100824/2008 [14]) targeted to senior citizens. The medControl triggers alerts on top of the TV screen when the senior viewer needs to take his pills. MedControl was developed using the Microsoft Mediaroom Presentation Framework (PF). Over this iTV service a multi-modal viewer identification system was developed and used in the interviews (Figure 2). This multi-modal system comprises the ability to perform viewer identification through:

- PIN insertion using the remote control;
- Bluetooth pairing with the user mobile phone;
- Detection of RFID tags (in an identification card).

A laptop computer running the Microsoft Mediaroom Presentation Framework simulator was used as a STB at the interviewees' homes. A RFID tag reader and a Bluetooth driver are part of the prototype. The identification module, a Java based software (VIS- Viewer Identification System), reads the RFID tags, discovers the nearest Bluetooth devices and forward viewer identification data to the iTV service.

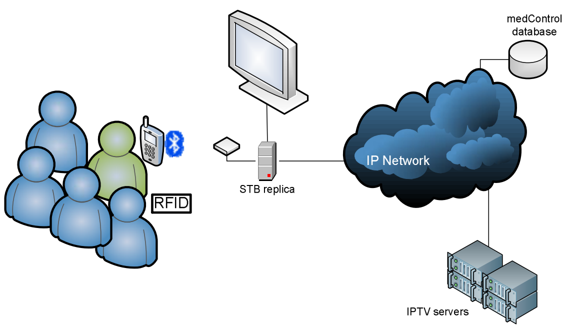

Fig. 2. Viewer identification system prototype

4.1.3 Interviews and Tests– Phase II

This set of interviews was useful to get insights of participants' experiences and to gather more depth information on the concerned topics [8]. This type of interview is common in the development of projects based on User Centered Design (UCD) [9]. In a top-level UCD definition we can characterize our strategy as Participatory Design.

Like in the first phase of interviews, we visit the participants at their homes in order to maintain them engaged at their natural environment. The researcher also tried to contribute to a relaxed environment making clear that it was not intended to test the participants' technical skills. This indication revealed to be quite important due to a "normal" reluctance by older people in talking about technologies.

The second group of interviewees included nine new participants over 55 years. The procedures adopted were similar to the first group of interviews. All the invited persons accepted, were very kind and demonstrated their willingness to help and to be interviewed again if necessary.

All, except one (due to a request from the interviewee), interviews were recorded. During the tests/interviews we could figure that the use of the prototype was very important giving the interviewees a solid and tangible image of the VIS goals. This evaluation helped us to improve the prototype and to get information about the most suitable viewer identification system. Along with the prototype we also proposed other identification options (same as in phase I) and we tried to perceive which the preferred one was.

4.1.4 Selected Findings

The collected data (from interviews phase I and phase II) shows that the estimated time spent watching TV (from all the participants) is more than two and a half hours a day. Specifically from phase II interviews, we gathered:

- Despite all the interviewees were familiarized with a TV set, we observed that they use the remote control mostly to control volume and select channels (6 in 9 users).
- All the interviewees considered the identification system useful and recognized the enhancements that can be obtained in iTV services based on it;
- Four of nine of the interviewees referred that the VIS should be as automatic as possible;
- Communication services and life support systems, specially related with medical care, were often referred as a key enhancement that could be obtained if a viewer identification system is implemented;
- Help instructions should be largely used and should be "always present".

In spite of these general indications our main focus was to detect a trend amongst the several automatic user identification techniques.

Concerning this, we found:

- The spectrum of answers about VIS was considerably large making not possible to clearly identify a trend (Figure 3). To most of the interviewees all the solutions could work depending on the help and explanation about it;
- Within the youngest participants (that were also more comfortable with ICT) there is a clear willingness to accept a regular VIS based on a PIN code. They can cope without a more advanced and automatic system. One of the interviewees (a 56 years old interviewee) referred the possibility of use the same profile wherever she is, using PIN code as identification system. This implies a centralized (in the provider infrastructure) mechanism of viewer identification.
- It was also possible to identify a light trend to face recognition method, probably explained by an indirect feeling that this is the easiest system to use.

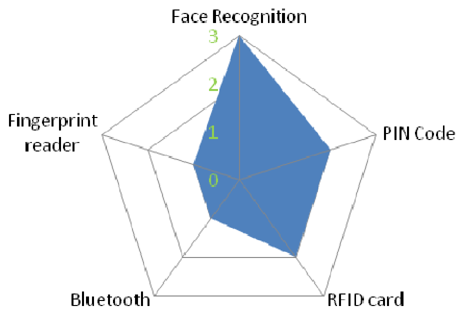

Fig. 3. Preferred identification system (depicts only the methods that were voted)

5 Conclusions

At the beginning of this work we aimed to identify a trend concerning a VIS and we defined a simple research process. We also realized that it is very difficult to illustrate and explain our ideas without a tangible prototype.

Although the results of the interviews were non-statistical it was clear that this is an excellent mean to involve and explain to older persons technological enhancements in interactive TV area.

In addition, this approach close to UCD helped us to clearly define relevant features, like how elderly will use the medControl module and to gather inputs for the next design phase of the iNeighbourTV project.

Regarding the Viewer Identification System, we cannot clearly identify a general suitable method (as depicted in Figure 2) but it is possible to identify that each user, in a specific context, tends to prefer a specific technique.

It can be concluded that to identify a specific solution a trade-off of some variables must be considered.

6 Future Work

Although we will be involved in the design of a multi-entrance matrix that will help in the definition of the most suitable VIS for a specific context, new interviews we will be conducted in parallel with the participation of younger people (aging between 30-40 years old) to understand if a relationship between age and dispersion of preferences comes out.

In the forthcoming phase of this work we will design a decision matrix based on the following variables: i) user's technological experience; ii) iTV functionalities; iii) level of physical disabilities of the viewers; iv) cost of the solution and technical viability; v) identification effectiveness; and vi) identification reliability.

We also intend to define a set of added value services target to the elderly to understand if, with this reward, the viewers will be even more motivated to incorporate the usage of a Viewer Identification System.

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Participatory Design of a Social TV Application for Senior Citizens – The iNeighbour TV Project

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Abstract. In this paper, we present the on-going work of the iNeighbour TV research project that aims to promote health care and social interaction among senior citizens, their relatives and caregivers. The TV set was the device chosen to mediate all the action, since it is a friendly device and one with which the elderly are used to interact. A study, conducted among the project's target audience (TA), using a participatory design approach is addressed in the paper. Its purpose was to better characterize this type of users; identify relevant features; and evaluate usability and user interface requirements targeted to television (in an IPTV infrastructure). The analysis of the study results, which ensured the revision of the project's features, is also presented along with a comprehensive description of the validated features. Some of these include: automatic user recognition system, medication reminder, monitoring system (of deviations from daily patterns), caregiver support, events planning, audio calls and a set of tools to promote community service.

Keywords: Healthcare, Social Interactive television, Medical reminder, Communication.

1 Introduction

The world's population is ageing, due mainly to life expectancy increase and the decline of birth rate. The elderly population is steadily increasing and according to the Portuguese National Institute of Statistics (INE) the number of people over 65 years old (1.901.153) is now higher than children under 14 (1.616.617) [11]. Although these numbers may vary from country to country, this is a problem that governments from developed and some developing countries will have to deal within the coming years. In a few years the costs with social security might increase strongly and, there could be difficulties in providing enough health and home care professionals to the entire elderly population. This might isolate this group even more and increase the associated problems such as loneliness and mobility issues. For this reason, society must find ways to control the rise of costs and ensure the quality of life of the elderly. In response to this, the European Community proposed an Action Plan "Ageing well in an Information Society" [24] with the following objectives: i) *Ageing well at work*; ii) *Ageing well in the community*; iii) *Ageing well at home*.

M.M. Cruz-Cunha et al. (Eds.): CENTERIS 2011, Part III, CCIS 221, pp. 49–58, 2011.

These problems can be more apparent in non-rural areas, where senior citizens are less acquainted with nearby neighbours who may share their interests and social contexts. This tendency might be overruled with the intervention of social tools equipped with features regarding the presence and needs of users in similar social circumstances, leading to higher levels of comfort, companionship and social interaction between senior users.

In this context, the present research aims to take advantage of the gained know-how on Social TV to develop the iNeighbour TV - an interactive TV application targeted to senior citizens. The development of the application is financially supported by the FCT (Foundation for Science and Technology) and its main objectives are to contribute to the improvement of the quality of life of the elderly and to minimize the impact of an ageing population on developed societies aiming a virtual extension of the neighbourhood concept. It is also intended that the system allows the identification and interaction of individuals based on: i) Common interests and television consumption; ii) Geographical proximity; iii) Kinship's relations – with its inherent companionship, vigilance and proximal communication benefits and; iv) Friendship relations.

2 Target Audience

The elderly represent a target audience (TA) considerably heterogeneous in terms of digital literacy, willingness, social behaviour, etc. This makes the development of this type of applications more complex demanding a previous and balanced definition of this TA. For the purpose of this study, the research team as decided to focus on the case of the Portuguese elderly.

According to the World Health Organization, Human age stages are classified as follows [20]: Adult age (15-30 years old); Mature age (31-45 years old); Transition and intermediate age (46-60 years old); Less Old (61-75 years old); Very Old (76-90 years old). According to the Portuguese National Institute of Statistic (NIS), by 2009, 17,9% of the Portuguese population was elderly from 65 years old on [11]. Most of the Portuguese elderly population is inactive (83,3%) [12], and the number of families composed solely by elderly is increasing (more 36% from 1991 to 2001) [13]. This might have contributed to place seclusion as the second biggest problem among the Portuguese elderly population [18].

2.1 Elderly and Multimedia

Some of the features idealized for the iNeighbour TV application are based on common web applications (e.g. social networks with presence awareness and text or voice chat) so it is mandatory to understand how the target audience uses the Internet.

In Portugal, according to the Lisbon Internet and Networks Institute [15], 6.3% of the population in the 55 to 64 years old age group are regular Internet users. The percentage is lower in the group over 65 years old, where only 1.6% uses the Internet [15]. In the 55-64 group, the following services are mainly used: i) Email, (by 91.4% of these users) specially to communicate with family members; ii) Instant Messaging (IM) (65.7% of these users); iii) Chat; iv) E-banking and; v) Virtual travel, the elderly like to make virtual visits to places they do not have the chance to visit in person [15].

Czaja [8] states that elderly are able to learn how to use a computer and take the most of it. The downfall is that it is difficult to standardize a learning program for them. Each individual has its own life experience, which means that each one has its own specific needs [3]. The same stands for the interface design. Due to the great variety of users within this target audience, Participatory Design [21] seems to be the appropriated approach. Nevertheless, guidelines from a previous study with elderly from two social institutions should be taken in consideration [9]. These include: i) keep it simple; ii) keep it clean; iii) include help buttons; iv) differentiate buttons with similar functions; v) allow the personalisation of the interface; vi) the application language should be in their first language; vii) value privacy; viii) different services means different functions.

According to a report from Marketest Audimetria/Media Monitor [17], Portuguese elderly watch an average of 5h30 hours per day, most of it during the evening (82%) [20]. Women watch more TV than men and the most watched programs are news, contests and soap operas, which seems to confirm that the elderly watch it mainly for companionship, entertainment and information [20].

3 The Social TV Domain

Although only recently acknowledge by the scientific community as a relevant research area within interactive television, a considerable amount of published works [7] that already address the definition and state of the art of the social TV domain is available. Analyses of applications like the ConnecTV [5], Collabora TV [19], Amigo TV [2], Telebuddies [16] or WeOn TV [1] reveal common characteristics, which the team believes will be equally important when senior citizens are concerned: i) communication with a friend, ii) "TV presence" – awareness of the TV channels that online friends are watching - sense of shared viewing and; iii) "see what I see" – the user can recommend a friend to watch the same TV show he is watching.

Different approaches to these subjects have been made and deserve mention. Some good examples are Ambient Orb [10], a light bulb that changes colours depending on the number of friends online, or IntegraTV for all [14] whose main goal is to make its services usable for everyone. By redesigning the user interface/contents and integrating a speech recognition system, that project aims to make digital television usable for everyone, including old people.

Recently some well-known TV set manufacturers have been producing televisions with access to numerous Internet services, including video calls using Skype [22] offering a way for the user to make video calls without the need to reach for a computer. These TV sets have the potential to become a valuable item considering their ability to retrieve relevant information from the web and provide complementary services by integrating widgets. However, at the present time, some of these features carry an extra cost for additional hardware.

Due to the target audience characteristics, health care is perceived as an important subdomain in this project. Therefore a comprehensive analysis of TV based services in this domain was conducted and we present two relevant projects.

T-Asisto. *T-Asisto [23] is a Spanish project that integrates tele-assistance services with television, using digital terrestrial television technology (DTT). This system integrates the common set top box used by DTT with a tele-assistance terminal that receives alerts from various types of sensors (gas, smoke, fire, movement, amongst others) scattered in the user's house. The terminal is also able to detect emergency calls by the user and has the ability to display the user's short message service (SMS) and appointments.*

BL Healthcare. *Companies like BL Healthcare [4] provide telemedicine features through a special STB that can also gather data from wireless peripherals and send it to medical professionals. While using the user's own TV set, the STB is only provided for BL Healthcare and is different from the STB used to decode television broadcasts.*

4 iNeighbour TV Features

iNeighbour TV is mainly a Social TV application but its intended contribution to the improvement of senior citizens' quality of life goes beyond the field of social relationships. Taking advantage of its communication and monitoring systems, it assumes a health care role by providing useful tools for both patient and caregiver.

The timeline of the research project comprises a period for the preparation and execution of a field trial during which the full application will be tested on commercial set top boxes (STB). This will give the team a chance to evaluate the project's impact in the quality of life of senior citizens.

Based in an in-depth analysis of the target audience specific needs, the research team conceptualized a set of features that aim to fulfil the identified requirements. These features are organized in five major areas: i) community; ii) health; iii) leisure; iv) information; v) communication.

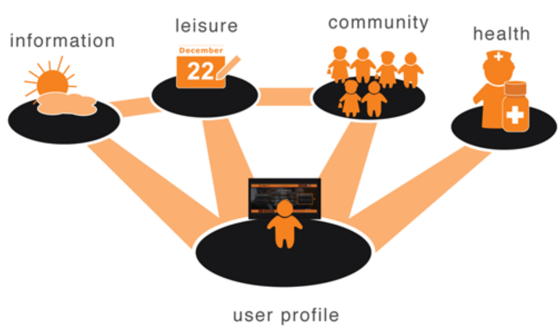

Fig. 1. iNeighbour TV modules

Each of the first four areas is assigned to its own module (community, health, leisure and information) while communication represents a set of features that are always present in the application and can be used in different situations to enhance other existent features.

4.1 Community

The community module is focused in socialization, isolation and loneliness issues addressed in the target audience's characterization. Its goal is to facilitate the establishment of new relations and strengthen existing ones through social interactions mediated by television.

This module is divided in three areas: i) friends; ii) news; iii) community service. *Friends* is the area where the user can manage his friend list, e.g. add a new contact by searching for existing users, using proximity, location and common interests as search parameters; *News* is similar to a social network wall that streams status updates from the user's contacts. Although, among the Portuguese population [15], people over 55 years old hardly use social networks, the research team wants to study alternative ways to promote face-to-face social interaction; *Community (service)* is an area where the user can search and apply for community service or voluntary work offers that match his skills and work history.

4.2 Health

This is one of iNeighbour TV's most important modules, because it aims to support one of ageing main issues, health. Providing features that address this part might help to improve the elder's autonomy by reducing its dependence, in certain specific situations, of health institutions.

This module supports the following five complementary areas: i) appointments - where the user can check an health schedule and get notifications or alerts about upcoming appointments; ii) contacts - supports a list of useful speed dial shortcuts to hospital, family doctor, emergency lines, pharmacies and others; iii) Recommendations - is the area where the user can look for governmental recommendations on how to proceed in several health related situations (e.g. how to proceed to avoid "H1N1" virus); iv) help videos - in this section the user will have several help videos to aid him with small health related issues that do not require medical guidance; v) medication control - a key feature of the iNeighbour TV. Health problems usually are felt more intensely in this stage of life, often leading to a medication dependence on an everyday basis. This can be a bigger problem when combined with memory loss issues also reported in this life period. For this reason, the research team decided to include a medication reminder system, which revealed a positive acceptance during the tests of the prototyped version.

Complementary to the features in the Health area, others transversal to the whole application also address health situations. Senior citizens often require permanent assistance or surveillance from relatives or health professionals - caregivers. By providing alert and monitoring features, accessible to a caregiver that is indicated and authorized by the elder user, the team expects to reduce the need for constant physical presence of the caregiver.

To ensure the referred support the system provides: i) a web application where the caregiver, or the senior user, manages the medication reminders. In this web application the user has access to the entire TV features plus the mentioned medication management tool; ii) TV base alerts and monitoring features. This includes medication and health appointments reminders. If a (scheduled) medication or appointment is missed an alert is triggered.

Along with this, the application keeps track of the user's television consuming habits - the system monitors it and when a significant variation occurs it triggers an alert. It alerts the caregiver or anyone else indicated by the elderly through TV based alerts, e-mail or SMS.

4.3 Leisure

As mentioned before, the elderly spend a lot of time watching television. Although TV is the platform chosen to implement this project, the research team aims that it can be used as a tool to promote a healthier life style. For this reason, features to encourage seniors to leave the front of the TV or even the house to socialize and to do physical exercise were conceptualized. The user has access to two areas in this module: *Events* with the aid of a wizard, the user is able to invite participants, define the location and set the date and time of different events: i) game – events like sports, card games, board games fit in this category; ii) walk/trip – e.g., a walk at the end of the day for daily exercise; iii) meeting – a night out with friends, a dinner at a friend's place; *Calendar* allowing a quick overview of what the user has to and might do.

4.4 Information

This module provides useful information to the daily routine: Weather reports related to the user's location. This information will be automatically displayed when the user creates an event that requires an outdoor activity; Pharmacies displays a list of nearby pharmacies, according to the user's location; Transports features bus and trains time schedules and itineraries. By default, the departure is the user's current location. This will again reduce the number of steps required to use this tool.

4.5 Communication

Several features of other modules rest upon the communication service, which makes it one of the core modules. It supports TV based text communication and, considering the elders potential problems with vision accuracy [6], it supports SMS reading and creation. Because of its dimensions, the TV set might present a good solution for this issue. Users of the iNeighbour TV will be able to read and reply text messages redirected from their mobile phone; But due to the difficulty to write long text messages (using the TV Remote or a virtual keyboard) and the target audience's habits on using the telephone, the audio calls, also supported in the system, might become the preferable method of communication.

To use all the referred features the user needs to identify himself in the application. For that the system features manual or automatic login support that guarantees that all the services provided are personalized. This is an extremely important requirement, especially when privacy and health care issues are concerned. As an example, it will allow to send the personalized medication reminding messages.

5 Preliminary Evaluation

The heterogeneous nature of this target audience enhances the importance of design and usability phase in this application. In order to prevent major changes in later stages of development, the team decided to conduct a participatory design approach. A sample of the TA was invited to participate in earlier stages of the design and interaction specification.

The specificity of this application, where the platform and target-audience are concerned, imposes some restrictions to prototype development. The preferable method would probably consist of a low-fi prototype running on a commercial STB. However, developing for this medium can be very slow and this approach could compromise the project's time plan. Therefore the team decided to narrow the aims of the test to four important parameters: icons, navigation, typography and transparency levels. This allowed the team to look for simpler prototyping techniques. After considering the most common methods such as paper prototyping, the team decided for a more out of the box approach. The prototype was implemented using an ordinary DVD-Video menu. This option allows testing in the intended platform (TV Set) using a similar interaction remote control (with directional keys) and in a familiar environment (participant's home). A total of 17 participants, aged from 54 to 72 years old, tested the application. The tests were conducted by an interviewer, which with the help of a small script ensured consistency through all the tests and accompanied the user through a series of tasks. The actions, difficulties and comments were registered in a spreadsheet to facilitate future analysis.

The first questions were targeted at the evaluation of the *icons' metaphors*. The evaluators were asked to identify each menu icon. The answers that were close to the icon intended representation were considered correct, because it is expected that when accompanied by a text label the users would make the correct interpretation.

Participants identified the icons that represent the weather, calls, messages, calendar and medication.

Fig. 2. The icons identified by the evaluators

They showed difficulties with the information and health icons, leading to a need for improvement. The profile, news, friends and events icons were flumped by the users and led to a complete review of its design.

After identifying the icons, the users experimented two different ways of *navigation*: horizontal and vertical. Results indicate that they do not have any relevant preference although the vertical option presented slightly better results. While interacting with the application, 55% of the users did not look at the remote while pressing the buttons while 45% did. This is another example of the heterogeneously of this TA where almost half are familiarized with this kind of technology and the other is not.

With the goal of identifying which *font sizes* the users feel most comfortable with, participants were asked to choose from five font sizes (12 to 16 points), presented simultaneously in the same screen to allow direct comparison. The smaller sizes (12 to 14 points) were completely rejected by the participants. 41% state that they can read clearly from the 14 points on. The 16 points option got exactly the same result (41%) while the 15 points stood on the 18%. According to these results, if the 16 points font size is used, almost everyone, besides acute visual deficiency users, would be able to comfortably read it.

Being iNeighbour TV an interactive television application, the team believes it is important to maintain the relation between the user and the regular TV broadcast. However, the use of *transparency* might disturb the elderly user. Therefore the team decided to verify this hypothesis. Participants were asked to identify the lowest level of opacity that they feel comfortable with (ranging from 85% to 100%). The majority choose the 85% opacity option, the lowest presented. This level of transparency offers a reasonable compromise between content readability and perception of the video footage in the background. This result gives the team a chance to develop a simpler and sleeker interface. The evaluated interface has a distinct characteristic; it only occupies the central portion of the screen, leaving the left and right side of the TV Set's canvas perceiving the television broadcast.

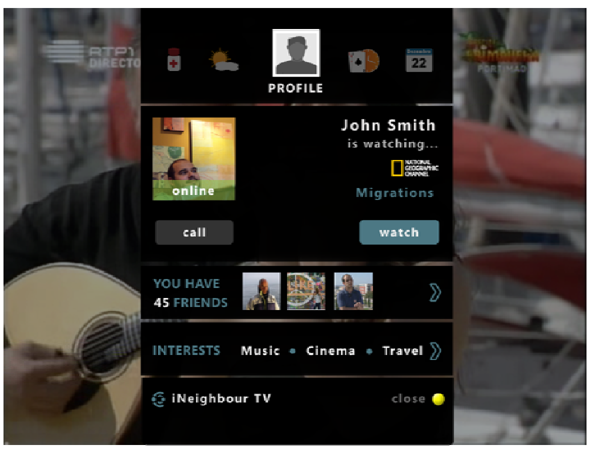

Fig. 3. The tested iNeighbour TV interface showing a user profile

During the design study there were some doubts concerning this option, which led the team to evaluate the possibility of the motion images in the background distract the user. Senior citizens were asked if the video disturbed, in any way, their experience. 64% of the respondents stated that the video did not cause any problem while using the interface. Like in the typography parameter, there was no unanimous result. Therefore, an adaptable interface, that would allow controlling the transparency levels of the interface and the background video, is recommended.

The research team took this opportunity of contact with the TA to validate the top features and areas planned for the iNeighbour TV application. The interviewer made a brief description of each functionality and questioned the interviewee if he or his fellow senior citizens, would use such a functionality. The following eleven features were presented: meteorology reports; audio and video calls through the TV Set; personal profile management; calendar; medication alert; the ability to read SMS and email messages on the TV screen; contacts management; wall stream and notifications with friends' updates; useful information like pharmacies and train schedules; health appointments and help videos; event planning. From the above-mentioned features only one would not be used by the majority of the elderly. (55%) stated that they would not use the SMS and email messages read service.

6 Preliminary Conclusions

The iNeighbour TV project aims to contribute in a field of expertise that, due to a global ageing population phenomenon, has become an important field of research. Researching on such an important subject is obviously highly motivational for the team but the heterogeneously of the target audience rose some concerns. The decision to perform a preliminary test stage, with a short sample of the target audience, has produced good results. The team has now a set of indicators and suggestions concerning Design and Usability that will allow adjusting the project guidelines in order to ensure a final product offering a better user experience. The positive feedback about the project's concept and key features, also gathered during the early testing period, has given the team extra motivation to continue its work. It is now clear that the efforts and resources invested in this research are appreciated and the results of our work might have real impact in the improvement of senior citizens quality of life.

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An iTV Audio Description Service: Suggesting Requirements and Features for Visually Impaired Users

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Abstract. The ongoing Digital Terrestrial Television (DTT) switchover leads to an interesting opportunity for the implementation of advanced television services. Actually, these services can even be interactive, since it is foreseen that the required Set-Top Boxes (STB) could be equipped with an Internet connection. However, among the future clients of DTT there are a large number of elderly and visually impaired people who can not entirely benefit of these services due to their physical limitations. Nevertheless, considering that Interactive Television (iTV) services can contribute to improve life quality of this type of users, it is essential to apply accessibility, usability and design-oriented guidelines for their development. In this context, this paper introduces a research related to universal design applied to iTV, being its aim to propose an advanced and accessible audio description service. In order to perceive the visually impaired users' problems and needs, a group of individuals was asked to participate in an interview.

Keywords: Audio Description, Interactive Television, Universal Design, Visual Impairment.

1 Introduction

Over the latest years, Television has suffered several technical changes that allow a transition in viewers' behavior, enabling them to benefit of an interactive resource with great potential. This metamorphosis inherent to the Interactive Television (iTV) concept allows viewers the use of new services, in which they can take an interactive role. In this context, the release of Digital Terrestrial Television (DTT) in Portugal presents itself as an important opportunity to the implementation of new advanced iTV services– specially in the cases when the required Set-top Boxes (STB) are provided with an Internet connection. It is predictable that most people will not have problems dealing with this type of services because they do not require specific know-how. However, as users have to deal with on-screen instructions and buttons on the remote control, elderly and impaired people would be excluded from using it.

According to 2001 Portuguese Census data [1], 6.1% of the population (approximately 650 000 people) has some type of disability, where visual impairment represents 1.6% (approximately 170 000 citizens) of this value. Thus, the creation of inclusion strategies becomes essential for increasing digital literacy and citizens'

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ability to participate in different areas. During a survey organized by the Lusófona University [2], 45.3% of participants answered not having a commercial TV solution at home and 96.7% stated having an analog TV. This is a considerable number of potential DTT users in 2012 upon the switchover of analog television.

For these reasons, the majority of this considerable number of users probably will switch to DTT since it will be the only economic way for them to keep enjoying television. Thus, it will be of paramount importance to take in consideration not only a well-structured transition but also the migration of the existent TV services. The foreseen agenda is also a relevant opportunity to apply accessibility, usability and design-oriented guidelines to this type of services and, eventually, to improve some of them, as is the case of the audio description.

In this context, this research aims to propose a set of requirements and features to develop an interactive audio description service that meets the needs of visually impaired users, based on an interview that allowed the identification of the difficulties and needs of visually impaired users (VIU) as consumers of television contents.

This paper begins by presenting the prevalence of visual impairment in the world as well as the different levels of visual function, followed by an explanation of the audio description on TV. After that, we describe the research process and suggest a set of requirements and features to develop an interactive audio description service. Finally, we formulate the conclusions and talk about the work to be done in the future.

2 Visual Impairment

All over the world there are 284 million visually impaired people, 39 million of them are blind and the remaining 245 have low vision [3].

In 2006, The International Classification of Diseases recognized four levels of visual function, namely: normal vision, moderate visual impairment, severe visual impairment and blindness. The term "low vision" aggregates both moderate and severe visual impairments and, consequently, all visual impairment are represented by low vision level and blindness condition.

According to the World Health Organization [4] a "low vision" person has a visual acuity less than 6/18[1] and equal to or better than 3/60 in the better eye with best correction. On the other hand, "blindness" is the inability to see and there are two types [5]:

- Chronic blindness – which includes cataract, glaucoma, age-related macular degeneration, corneal opacities, diabetic retinopathy, trachoma, and eye conditions in children (e.g. caused by vitamin A deficiency);
- Blindness caused by infection – which is decreasing, due to efforts in developing public health actions.

Cataract pathology is the leading cause of visual impairment in developing countries (47,9%), despite all the advances in surgical techniques during the last ten years [6].

[1] This means that in a distance of 6 meters, a person with visual impairment sees what a person without vision problems sees at a distance of 18 meters.

In 2002, other main causes of visual impairment are glaucoma (12.3%), age-related macular degeneration (AMD) (8.7%), corneal opacities (5.1%), diabetic retinopathy (4.8%), childhood blindness (3.9%), trachoma (3.6%), and onchocerciasis (0.8%) [6, 7].

3 Audio Description on TV

Generally, the audio description on TV is based on an audio track that is added to the television program and verbally describes what happens on the screen [8]. The main objective of this assistive communication media is to support blind and low vision users when viewing television programs. During audio description, a narrator describes the scenes and images on the screen, allowing a better understanding of the audiovisual narrative [9]. The audio description is made between the characters speeches and in sync with other narrative information: facial expressions, clothing, and environment. Thus, this technical aid does not overlap to audio content, but operates with it in order to provide a better understanding of a scene (Fig. 1).

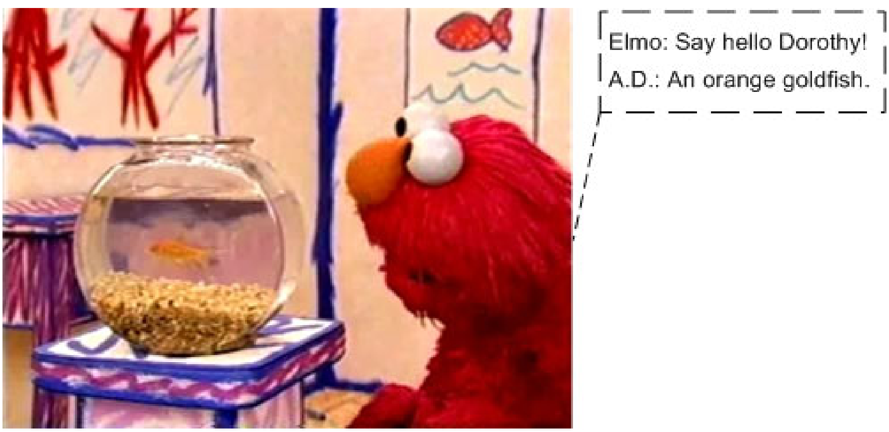

Fig. 1. Illustration of the audio description of ‘Elmo’s World’ [13]

In Portugal, the very first program to be broadcasted with audio description was the movie “Menina da Radio” (“Girl from the Radio”), broadcasted by the national television ‘RTP 1’, at the end of 2003 [10]. To have access to this service the user needed, and still needs, to use the radio and tune up the medium-wave (MW) of ‘Antena 1’ (a national radio station). In practical terms, the underlying model to this technique is based on two over-the-air frequencies: one supporting the television broadcast and the other a radio emission carrying the scenes and images description. Currently, people who are blind or have low vision can follow the series of ‘RTP1’ that have audio description using this technique [11]. At December of 2004, the audio description service on ZON (a Portuguese Cable TV provider) was released in a partnership with ‘Lusomundo’ channels (currently TVCine) [10]. This was the first (and the only until today) service focused on people with special needs broadcasted by a digital television provider in Portugal. The ZON's audio description process consists of an additional narration to the soundtrack of the audiovisual narrative. To access this service, ZON costumers should press the green button of the STB remote control and press "OK" on "Áudio Descrição" ("Audio Description") option [12]. Note that no additional information is provided about the access to this service provided by ZON.

At present, in some countries there are some interactive audio description services supported by the DTT, mostly developed on United Kingdom. However, beyond the audio service activation and alerts when an audio description program starts, these services do not have additional functions. Therefore, there is an opportunity window to create an advanced audio description service that is in compliance with universal design principles and meet the needs of its viewers/users.

In pursuing this goal the authors are developing an interactive audio description service supported by an interaction model that allows the access of visually impaired users in an easy and intelligible way.

4 Research Process

The technical requirements of the aimed system and the special needs of its the target audience implied the design of a specific research process that is described in the following sections.

4.1 Research Method

The method that supports this research is the Grounded Theory [14] in order to obtain a significant and sufficient data to determine the difficulties and needs of VIU as consumers of television contents. The Grounded Theory is based on methodological procedures that have as main objective the data analysis, described and organized in a gradual sequence that looks for the integration of these data.

Thus, it aims to collect and analyze data systematically, guiding researchers through an inductive method of knowledge creation. The reason for choosing this method is related to the target audience heterogeneity and the innovative characteristics of DTT interactive services, requiring that data be acquired before advancing to the structuring of a theoretical interpretation.

4.2 Sample

The sample that integrates this research was selected arbitrarily from patients at the low vision appointment at the Instituto de Oftalmologia Dr. Gama Pinto [15] with the help of an ophthalmologist. In total, 20 subjects with visual impairment accepted to be interviewed; 10 of which are blind and the remaining 10 having low vision (these users ranged from almost blind users to people with glasses capable of distinguishing regular subtitles).

In terms of age, 5 subjects are between 10 to 18 years old, 3 are between 19 to 34 years old, 7 are between 35 to 60 years old and finally, 5 are more than 60 years old. Fig. 2 illustrates the relationship between the sample's age and visual impairment type.

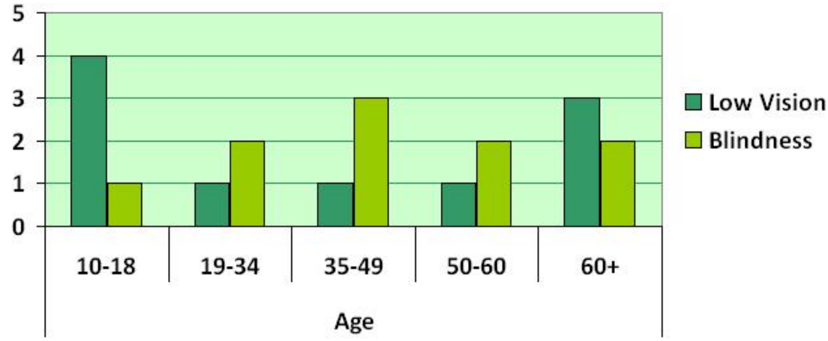

Fig. 2. Number of interviewees ordered by age and visual impairment type

Regarding the type of television service that the interviewees have at home, 12 of the subjects only has access to the four over-the-air channels provided by Portuguese analog television. The 8 remaining subjects have a commercial digital television solution; 3 are clients of an Internet Protocol Television (IPTV) service and the remaining 5 of a cable TV provider. Fig. 3 shows the relationship between the TV service that the interviewees have at home and their visual impairment type.

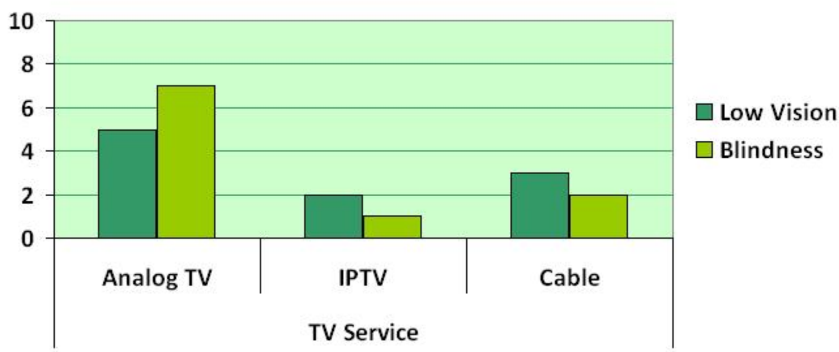

Fig. 3. Number of interviewees order by TV Service and visual impairment type

4.3 Interview Guide

A semi-structured interview was conducted to gather subjects' opinions about television and their problems in accessing and handle with it. According to Flick [16], the semi-structured interview became widely used because the interviewees' points of view are more easily expressed in an interview situation more open and flexible than a structured interview or a questionnaire. Consequently, the main advantages of this method are the greater depth of gathered data compared to the questionnaire and the inherent flexibility because face-to-face contact allows the explanation of questions and answers.

Thus, this type of interview was chosen not only to facilitate data processing, but also to give interviewees some freedom in their answers. The interview guide was structured in the following four parts in a total of 31 questions, mostly fixed-response.

- Part I – General Data

Each subject was asked to express his/her visual impairment type (low vision or blindness); to indicate how long he/she has had his disability; what their job is; and finally, what TV service he/she has at home.

- Part II – Television Consumption Patterns and Audio Description

In this second part, the subjects were asked to answer questions related to their TV content consumption patterns (e.g.: how much time in a day is spent watching TV) and their knowledge about audio description (e.g.: if they know about this communication aid and if they have ever used it).

- Part III – Television Access Problems

Two open questions were placed asking the interviewee to speak about his difficulties as a consumer of television content and how he/she believed these problems could be solved. When the subject did not provide much feedback, the interviewer gave some suggestions to solve their problems.

- Part IV – DTT and iTV

In the final part of the interview, the subjects were asked about their knowledge of Digital Terrestrial Television (e.g.: if they knows this technology) and also about iTV (e.g.: if they had ever contacted with an interactive television system and if so how they use it).

After the interview, through data processing, the research object was described and interpreted. We attempted to classify subjects' behaviors and procedures associated with the activity of watching television and also understand the problems they have to deal with in that situation.

5 Selected Findings

The interview results uncovered a significant number of findings, which are following presented and discussed.

- Television Consumption Patterns and Audio Description
  - Interviewees spend on average 2-3 hours a day watching television.
  - The television genres they enjoy the most (regardless of their visual impairment type) are: television series and movies (70 percent); information (70 percent); talk shows and game shows (50 percent); and sport games (10 percent).
  - 8 blind subjects say that they need help to adjust the television volume and other TV options.

  - All interviewees state that they use the remote control and learned themselves the location of the keys.
  - Only 5 subjects know what audio description is while 3 of them use it.
  - All subjects assign a high degree of usefulness to audio description.

- Television Access Problems
  - 4 low vision users say they have image contrast difficulties when watching TV.
  - 6 low vision users say they sometimes can not read subtitles because they are too small.
  - 1 low vision user and the 10 blind users say they can not understand certain things that happen in TV programs.
  - 5 of the mentioned above state they lose interest in the TV program they are watching.
  - In regards to the solutions proposed by interviewees to these problems, the 10 blind subjects think audio description could solve their difficulties. One of the users also thinks that the possibility of changing audio speed could help (Fig. 4).
  - Regarding low vision subjects, 6 consider that the zooming in of subtitles is a helpful strategy, 4 subjects believe that the option of changing TV image and subtitles contrast are useful ways to solve their problems and 2 subjects consider that dubbing could help too. Finally, 1 subject thinks that audio description could be a solution to their difficulties (Fig. 4).

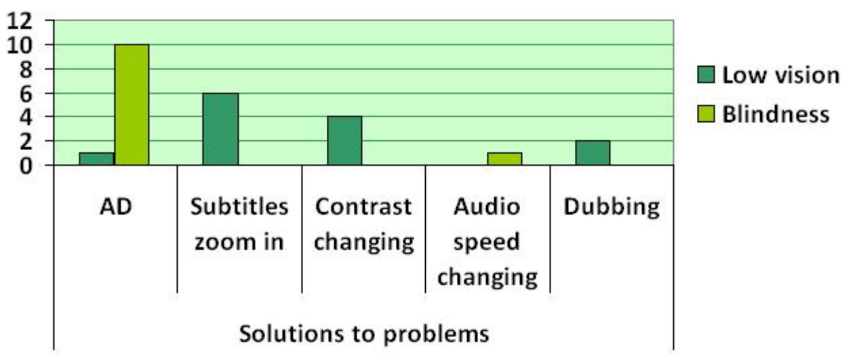

Fig. 4. Solutions given by interviewees to the problems they experience when they watch TV

- DTT and iTV
  - Only 8 subjects know what digital terrestrial television is.
  - 11 interviewees think digital terrestrial television will complicate watching TV.
  - 11 interviewees already had contact with an interactive television system.

- 7 of these 11 subjects say they had access problems when interacting with this type of system: they did not know the option that was selected, got lost in menus, did not know how to turn back and also could not read text because it was too small or had low contrast.
- 19 subjects think that an iTV audio description service on DTT is useful, where the user could access different features such as the selection of the narrator's voice (e.g. male/female voice) and the adjustment of the audio description volume.
- These interviewees considered other useful features that could be added to an iTV audio description service, such as: audio description warnings; voice feedback of the available options; changing of the language; and access to a list of their favorite channels with audio description (Fig. 5).

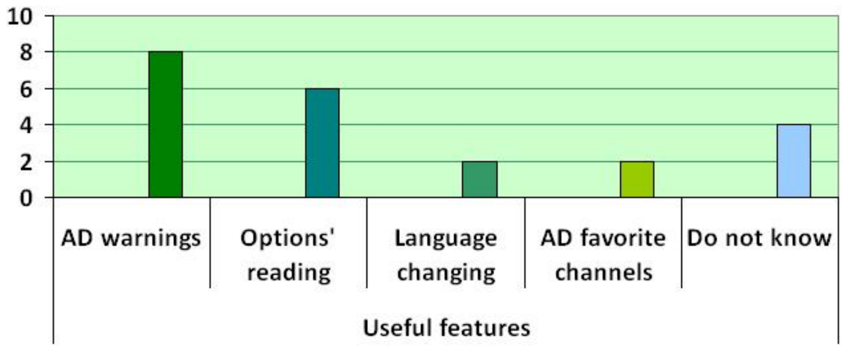

Fig. 5. Features interviewees would find useful in an ITV audio description service

6 Proposed Requirements and Features

The selected findings enabled the proposal of a set of requirements to develop an interactive audio description service that meets the needs of VIU, which is briefly presented here.

- Flexibility and Adaptability

The system must give the user the choice to perform image and font-size magnification of its menus and television content. In addition, it is important to have the option to adjust brightness and contrast of the menus.

- Audio Feedback

The system audio feedback must be triggered when the user accesses the menu options or when he selects any menu item. It is also valuable to have audio feedback when a program with audio description starts.

- Contextual Help

The contextual help option must always be present and accessed by a hotkey with some sort of relief.

- Audio Description Customization

The user must be able to choose the narrator's audio description voice (e.g.: female or male voice), the language (among those available in the TV program) as well as the control of the volume and speech speed.

- System Personalization

The system must be able to identify and filter programs with audio description on the EPG. As a result, the system must grant the user the possibility to choose what he wants to see from a list that includes all his favorite channels with audio description.

- User Automatic Identification

The system must be able to identify the user automatically. Consequently, when the user is identified, theirs preferences must be loaded and the system must adjust to them.

7 Conclusions and Future Work

Viewers with different backgrounds react in different ways to television technological convergence, a condition that sets up a specifically advantageous context for the consideration on the issues related to accessibility and inclusive design.

The presented research project aims to study new strategies for the integration of people with visual impairment on the Interactive Television scope towards the development of an audio description service interaction model that meets the specifications and needs of this type of users. Thus, this research aims mainly to help VIU's interaction in the iTV context and develop an interaction model that allows the access to an enhanced audio description service for VIU in an easy and universal way.

From the presented results, we can extend this research to a more practical level, namely in what concerns the conceptualization and specification of features that are consistent to the identified requirements and the problems experienced by VIU. The designed research process has been revealed suited to the support the development of a prototype of an advanced iTV audio description service that will be evaluated by low vision and blind users through accessibility and usability testing.

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A Multi-stream Tool to Support Transmission in Surgery Applied to Telemedicine

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Abstract. The increasing network bandwidth capacity and the diminishing costs of related services have led to a rising number of applications in the field of Information and Communication Technology. A special case is applications based on video streaming. Telemedicine can be highlighted in some scenarios for applying this technology, such as clinical sessions, second medical opinion, interactive lessons or virtual conferences. These scenarios often imply a dedicated transmission environment. A restriction in such solutions is the inability to handle multiple video streams. Thus, this paper presents a low-cost infrastructure for video collaboration in healthcare and based on open technologies. The proposed infrastructure enables remote management of simultaneous multiple streams. We also discuss results of experiments held in the Lauro Wanderley Academic Hospital, Brazil. One of the results is the contribution for teaching experiences, particularly by allowing students to remotely regard surgical procedures and providing real-time interaction. Finally, we present new prospects for using the developed technology on other applications in Telemedicine and Telepresence.

Keywords: Digital video, Management, Telemedicine, Collaboration.

1 Introduction

The domain of Information and Communication Technology (ICT) has been going through a notable transformation which is characterized by the global connectivity and the increasing use of multimedia devices. These factors have afforded the development of new transmission networks to handle large volumes of data and increasing power transmission [1], as the Internet2 [2]. High power transmission networks enable the development of applications that require a large bandwidth.

Actions directed to Telemedicine and Telehealth is growing around the world at an accelerated pace. Large technology companies like Polycom [3], Tandberg [4] and Cisco [5] are investing heavily in these areas. Cisco, for example, presented, in 2010,

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the Cisco HealthPresence, at the Healthcare Information and Management Systems Society (HIMSS) Conference. Cisco HealthPresence is a new technology in advanced Telemedicine that enables remote medical appointments, with features and technologies never used before. All of this combining high-definition video and high quality audio, as well as enabling medical data transmission, which gives the patient the feeling of being in a face-to-face appointment. According to Lima [6], among the several forms of Telemedicine there are videoconferences, which allow real-time integration, by sending and receiving high-quality video and audio along geographically distant points. Thus it is essential to ensure a secure data transmission.

Therefore, this paper presents a tool consisting of a set of components that together allows the easy management of several streams, controlling everything from capture to display in an efficient and intuitive way. We present the main actions related to the development of tools for remote multimedia streams management in order to illustrate the state-of-the-art in this field. The main characteristics obtained from this study compose the basis of the architecture presented in this paper. Finally, we present results and feedback from the use of the tool in real environments.

2 Related Work

In order to characterize the state-of-the-art we highlight in this section two projects and developed tools. The analysis of related projects gives higher importance to the works developed in the institution which were indispensable to the current work. On the other hand, the analysis of the tools allows comparing this work face to other tools which implement similar features, as described in sequence.

2.1 Projects

The Digital Video Workgroup [7] had the main goal which was developing and deploying an infrastructure based on the RNP (National Network for Education and Research) network that offers support to applications involving digital video manipulation. Another responsibility of this workgroup was motivating and providing the necessary conditions to create, store and transmit digital video content around the country – Brazil – by the use of two developed tools: JDLive [8] and JDVoD [9]. The first one is a server for transmitting high and low quality digital video. The latter is a video-on-demand server.

The GingaVR [10] project aimed at developing and demonstrating a platform focused on the creation of immersive virtual reality applications over high speed networks. One challenge of this project was to allow the remote control of a robot, associated to the transmission of several synchronized high quality and real-time video streams, as well as the exhibition of these video streams in a Digital Cavern.

The Digital Media and Arts Workgroup (GTMDA) [11] focused mainly on providing a new advanced way of Human-Computer Interaction, which allows the intermingling of human and synthetic agents in shared and distributed real-time multimedia spaces, all over high speed computer networks with large volumes of data.

The Video Collaboration in Health Workgroup (GTAVCS) [12] proposed an infrastructure based on hardware and software with remote management for capturing and securely distributing multiple simultaneous streams in order to provide support for several scenarios of video collaboration in health.

2.2 Tools

There are several studies in the literature with the main goal of manipulating digital media, specially, digital video. The most relevant are described below.

DICE [13] is a tool that manipulates real-time video, by the use of filters. These filters applied to the videos are nothing more than the manipulation of pixels that, when combined mathematically, creates new images from a real-time video stream. This tool was developed only for Apple Macintosh platform and is limited to the use of filters on local real-time video streams captured from cameras plugged on the computer, i.e. it does not use any transmission system of TCP/IP protocols stack.

Grass Valley 300 [14] is a device whose main purpose is to switch multiple real-time or pre-recorded video sources. These input sources can be capture through composite cables (analogical) or via serial or parallel cables (digital). This device enables capturing a total of 64 different sources and switching them to any output by manipulating buttons and levers. Despite of being a device highly professional, it is limited to local video manipulation. Another setback is its purchase or rental cost.

SuperCollider (SC) [15] is an environment and a programming language for real-time audio synthesis and algorithmic composition. Since version 3, the environment is divided into a server and a client that communicate to each other via sockets by using the Open Sound Control (OSC) 6 (CNMAT). The SC server supports single plugins made in the C programming language, which makes it easier to develop algorithms for efficient manipulation of sounds. All external controls on the server are made via OSC. On the server side the sound generation process is via an optimized executable line command called *scsynth*, which in most cases is controlled by the SuperCollider environment, but which can also be independent. In this environment, insertion and manipulation of sounds over the network occurs in real-time using the TCP/IP protocol. Another point to be highlighted is that SuperCollider is developed under the GNU Generic Public License (GNU GPL), or just free software, which makes it a suitable environment to be added into other free software projects requiring real-time audio manipulation.

INTERACT [16] is a software used by many researchers who need to collect data in observational studies of multimedia environments. It allows the user to interact with their audio/video material, analyzing it by pressing a few keys on the computer or using the mouse. It is possible to manipulate parts of the video, allowing going into actual details of the scene. It can also integrate any external data, such as physiological information or data stored on the hard disk, offering a wide range of possibilities for visualization and analysis such as statistics, reliability analysis and sequential analysis in a time interval.

The TVSL [17] is a tool that captures video and audio content and sends them to Icecast servers. It has a graphical user interface that displays video streaming, allows the application of video effects dynamically and allows setting the parameters of the transmission. In the use of TV Free Software (TVSL), it was identified the requirement of a software that meets the task of capturing audio and video, transcoding and streaming multimedia (stream) to Icecast 2 servers. There are different methods for transmitting, using and combining programs that perform each of the above tasks. So, in this scenario, it has been developing the TVSL as the main program to setup TVSL transmission, allowing real-time capture and encoding of different video and audio inputs from external devices such as firewire cameras, USB webcams, and PCR and DVB cards.

2.3 Comparative Analysis

Table 1 presents a comparative analysis among the tools described in section 2.2. The tools were analyzed regarding their TCP/IP support, audio streaming, video streaming, statistical data generation, and if each one is a distributed system.

For example, in telemedicine is required that a tool allows the connection of remotely distributed users (distributed system), statistical data generation enabling transmission simulation, as well as that is provides TCP/IP support. These requirements were, therefore, used as the basis for developing our tool, described in the next section.

Table 1. Comparative analysis among tools

	TCP/IP Support	Audio Streaming	Video Streaming	Statistical Data Generator	Distributed System
Grass Valley	No	Yes (only locally)	Yes (only locally)	No	No
SupperCollider	Yes (only audio)	Yes	No	No	Yes
DICE	No	No	Yes (only locally)	No	No
INTERACT	No	Yes (only locally)	Yes (only locally)	Yes	No
TVSL	Yes	Yes	Yes	No	Yes

3 The Developed Tool

The main objective of our tool is to remotely manage and coordinate distributed multimedia sources with different media encoding formats. Following, we present its main developing models: conceptual, architectural, component and security models.

3.1 Conceptual Vision

The tool uses any network that gives minimum support for high definition streams (1440x1080) at rates of 25Mbps and standard definition (720x480) at rates of 4Mbps or 8Mbps depending on the compression technique used. These streams can be generated locally or in different geographic locations and they are controlled and managed by the principal component of our tool, the *Articulator*.

3.2 Architectural Vision

The architecture illustrated in Fig 1 shows the components articulator, decoder, encoder, reflector, videoserver, videoroom and webservice. It also shows the possibilities for transmission rates: high quality (HD, SD) and low quality (mainly directed to the Web).

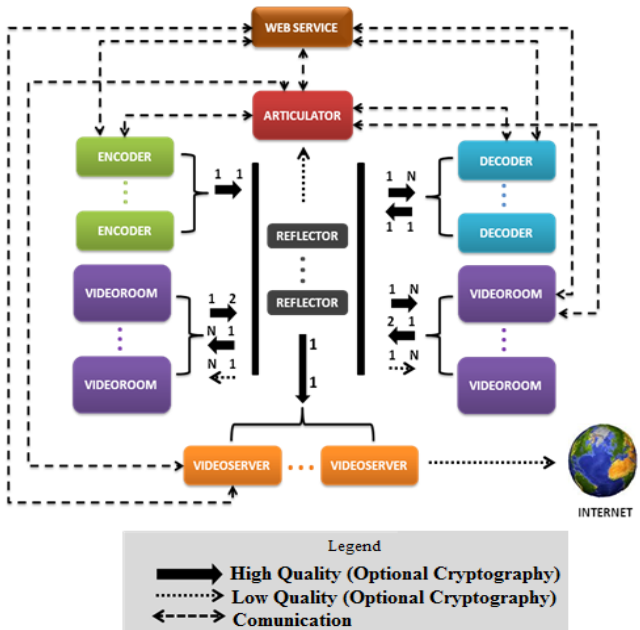

Fig. 1. Architectural vision

3.3 Component Vision

It can be seen at the previous topic that the tool uses a distributed architecture based on functional components. The main ones are: encoder, decoder, videoroom, webservice, reflector and articulator.

The *encoder* is responsible for making the media source encoding, which can be either a capture device or files stored in the hard disk – AVI, WMV or TS files. It is also responsible for streaming and sending the captured media to a *reflector* that will distribute the stream to the targets set by the *articulator*.

The decoder has the main feature of capturing a single media stream and decoding it in order to display the media on an appropriate device. The capture of the stream is done via a UDP port, which is automatically combined in advance with the *articulator*.

The *videoserver* has the core functionality of streaming low resolution video to the Web in various formats, specifically popular file formats used nowadays, such as FLV, OGG and H.264, allowing a wider range of options for users viewing the video streamed to the Internet. But to broadcast the media in different formats, it is required a robust machine that can perform the original audiovisual content transcoding.

The *videoroom* encloses the functionalities of *encoder* and *decoder* components, which makes easier the simultaneous communication with multiple clients. The development of this component had the main goal to meet an easier configuration of capture and display devices in a surgery room. Spaces such as surgery rooms are usually limited. Moreover, considering infectious disease control issues in a surgical environment it is advisable to concentrate on a single device the functions of capturing and displaying media.

The *webservice* main features are (a) create/update session, (b) create/update user, (c) insert or remove user from a session, (d) finalize a session. Sessions are composed of encoders, decoders and/or videorooms. In each session, you can isolate a specific configuration of components so that you can forbid access for unauthorized users to a particular audiovisual content. Thus, a single articulator is capable of manage various audiovisual sessions. This component meets requirement of easily manage multiple independent surgeries within the same hospital, for example. Thus, the content of each session (i.e. each surgery) is restricted to authorized users, who may be Medicine students, residents or doctors within the surgery room.

The *reflector* optimizes the distribution of media streams over the network. This component works in two different scenarios: one is the direct send of stream to a *decoder* or a *videoroom*, at the same rate it received; the other scenario is characterized by transcoding the media into a lower rate, in order to send it to the *articulator*.

The *articulator* is the principal and most complex component. It is responsible for remote managing all others components, enclosing much of the functionality offered by the tool. One of its main features is the scheduling of video streams, with which you can program the hour when media streams are sent from *encoders* to *decoders*.

3.4 Security Vision

The strategy developed is based on the authentication of all video sources and destinations, as well as the transmission of encrypted media streams.

One way to address the secure transmission of multiple streams is sharing a symmetric key for each pair of users (source/destination). However, this strategy is not feasible due to the high cost of processing the encrypting the stream for each destination, since the encryption key is different for each pair of users. In order to handle this limitation, the concept of session is an alternative. A session is defined as a space created to group users and share data in a deliberative meeting. A session can be moderated or not, which implies giving permission to access any information to all users or only for guest users invited by the creator. In order to obtain the unique symmetric key of a particular session, the user needs to authenticate in the session. Authentication is accomplished through queries to a database of users located in a centralized server and the communication is done using the *Rivest-Shamir-Adleman* (RSA) algorithm 1024 bits [18].

Among the features to be protected there are the streams sent between users in the session. The streams are encrypted and decrypted using the *Advanced Encryption Standard* (AES) algorithm 128 bits [19] with shared symmetric key of the session.

4 Case Study

The use of the tool in telemedicine involves a proposal for transmitting surgeries in two academic hospitals of RUTE Network: São Paulo Academic Hospital at UNIFESP and Lauro Wanderley Academic Hospital (HULW) at UFPB. In both cases it is required remote management, media capture and secure distribution of multiple simultaneous streams (video, audio, and clinical parameters).

In the first case - São Paulo Academic Hospital, UNIFESP - the goal was transmitting a surgical procedure, namely transapical heart valve implant. The transmission used four simultaneous video streams. In such procedure, a prosthesis is used to replace the problematic valve. The prosthesis can be implanted through a minimum cut, which leads to the chest via a catheter. During the procedure, the heart continues beating and the equipment for extracorporeal circulation is not necessary. This is a high complexity procedure; therefore, students and other professionals in loco have considerable difficulty to visualize the details during the surgery. Fig 2 shows the dynamics of this procedure where we can see the large number of people in the room.

In order to deal with the problem of little free space in the surgery room and to allow a larger number of viewers, the tool was used to provide interaction between the professor/physician in the operating room and other geographically distributed participants.

Fig. 2. Surgical procedure illustrating a medical lesson

At the Lauro Wanderley Academic Hospital (UFPB) the tool has been used for transmission operation. In these experiments, multiple streams were transmitted between the surgery room, where the procedure was performed, and the telemedicine room, where students and teachers could interact and follow the procedure in real time. The procedure transmitted was an inguinal hernia surgery using laparoscopy as can be seen in Fig 3.

In this experiment, while a surgeon performed the surgery another doctor followed the procedure with their students in the telemedicine room at the HULW as can be seen in Fig 4. Doctors could interact via audio and image at any time of the surgery. Two cameras were used during the experiment: the endocamera (internal view) and another camera responsible to capture the external view of the procedure.

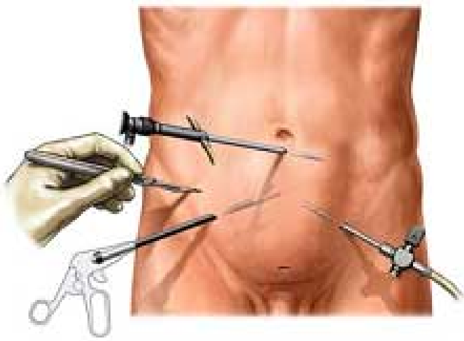

Fig. 3. Schematic view of the surgery

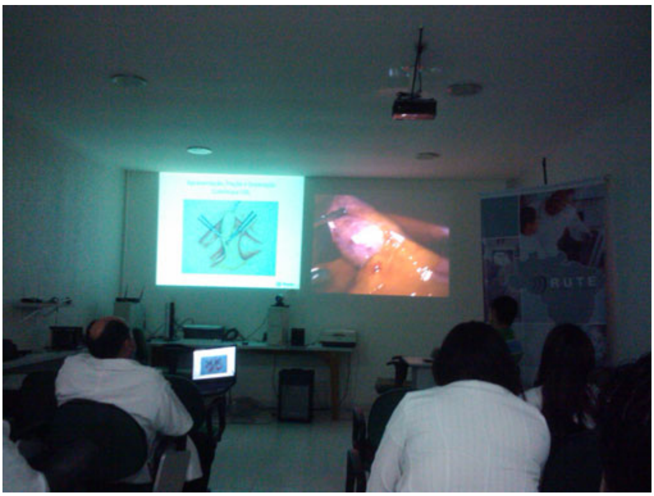

Fig. 4. Telemedicine room at HULW during experiment

Fig 5 shows the articulator, module that manages streams captured by encoders and displayed by decoders. We can see the streams that are manipulated during surgery.

The surgery room and the telemedicine room sent and received streams, which allowed interaction among participants of the two rooms. A multimedia stream was captured in the telemedicine room and displayed in the surgery room and two multimedia streams were captured in the surgery room and displayed in the telemedicine room, but only one was displayed at a time. These flows were switched according to the need for participants to see the surgery from different angles. Researchers at LAViD followed the events of both rooms, but no stream was sent to any of the rooms.

The experiments had good assessment of physicians, Medicine students and researchers from LAViD. There is an expectation for similar activities and the possibility of adopting the method as part of classes conducted in the hospital.

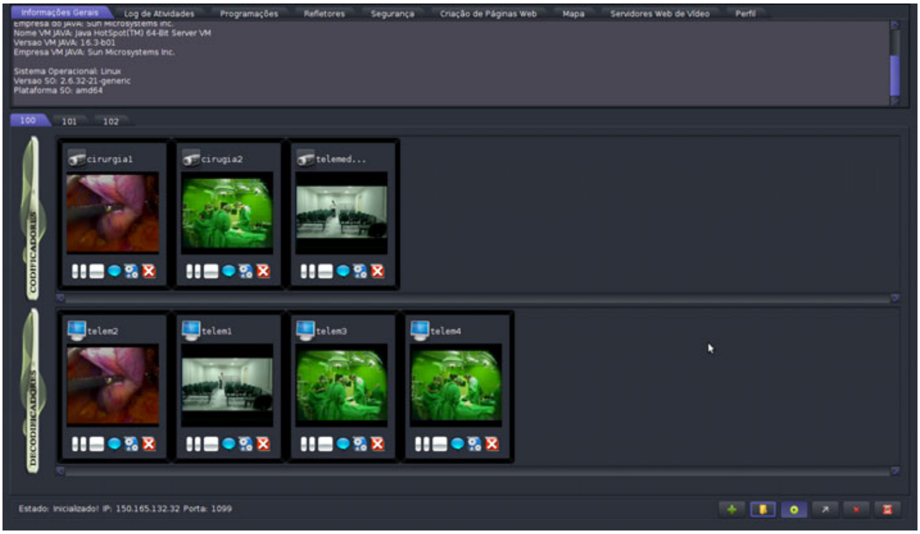

Fig. 5. Articulator managing the transmission at the Lauro Wanderley Academic Hospital at UFPB

5 Conclusion

The use of specialized tools for managing streams in artistic or sports events, or experiments such as telemedicine or tele-education, reduces operational complexity and increases the possibilities of transmission. Therefore, the tool presented in the current paper aims to contemplate such scenarios as an integrated solution for managing distributed real-time multimedia streams. The tool provides support to coordinating different multimedia sources in order to facilitate the interaction among virtual and human agents. With only computers, cameras and/or projectors it is possible to any user starting its own transmission in a simple and low-cost way.

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Introducing Innovative Business Processes in Enterprise Functioning: Case of Telemedicine Processes

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Abstract. Introducing innovative Business Processes in Enterprise functioning is dealt with according to a specific approach; different from that generally adopted in Business Process Reengineering projects. This is the case of introducing telemedicine processes in hospitals/clinics functioning. The main characteristic of the proposed approach is the fact that it doesn't take into consideration existing processes but directly examines objectives and vision of to-be processes. This work is based on two case studies, both related to telemedicine. They respectively concerned tele-radiology process and tele-consultation process. These case studies allowed us to validate the proposed approach which was well adapted in both cases.

Keywords: Innovative business process, Business process reengineering, Case study research, Telemedicine, Tele-consultation, Tele-radiology.

1 Introduction

Technological change and globalization nowadays oblige contemporary firms to be efficient in order to ensure their sustainability. Change in nowadays companies has become a necessity rather than a circumstance. Change is generally defined as any transformation of an enterprise or a part of an enterprise in order to track changes in its environment [1].

Multiple methods of change management exist in literature [1] such as TQM (Total Quality Management) which provides a gradual improvement in business processes but is very spread out over time, benchmarking which consists in learning how successful companies are organizing their processes and BPR (Business Process Reengineering) to which we are interested in this paper.

BPR (Business Process Reengineering) is defined as the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical contemporary measures of performance, such as cost, quality, service, and speed [2].

Several methods of conducting BPR projects are defined in literature [3], [4], [5], [6], mainly including the steps of vision, initiation, diagnosis, re-design, implementation and evaluation. All these methods use a task of process modeling for both existing business processes and newly designed ones.

Several problems arise during BPR projects undertaken by contemporary companies, such as: the difficulty to model as-is and to-be business processes, the lack of

M.M. Cruz-Cunha et al. (Eds.): CENTERIS 2011, Part III, CCIS 221, pp. 79–88, 2011.

guidance and the failure to consider contexts in BPR projects. Such contexts include the nature of the considered processes and their specificities.

Our paper focuses on issues concerning BPR projects integrating innovative processes. The proposed solution is a methodology which deals with different concepts involved in reengineering projects integrating innovative processes. This methodology is adapted to BPR projects concerning innovative business processes.

This methodology of BPR, taking into consideration the specificities of innovative processes, has been instantiated in two case studies both related to the area of telemedicine. In these case studies, instantiating the methodology allowed the understanding and then the integration of innovative processes.

This paper is organized in the following way: in section 2, special consideration of innovative processes is presented. In section 3, case studies related to BPR projects integrating telemedicine innovative processes are presented. In section 4, deductions are presented. Finally, a conclusion and future works are presented.

2 Special Consideration of Innovative Processes

Business Process Reengineering Projects related to "innovative processes" have to be treated in a particular way. The "innovative processes" are those to which people and companies have not yet developed traditions (or habits) and have not yet established the best way to practice them. They must be managed in a different way [7]. Thus, they could be studied without requiring prior detailed consideration of the old processes. For such processes, innovating aspects and especially technological aspects appear from the beginning of the project through goals that have to be reached, generally expressing the new ways of proceeding and the technologies that must be adopted [7]. In such a context, a new organization of actors and tasks is necessary.

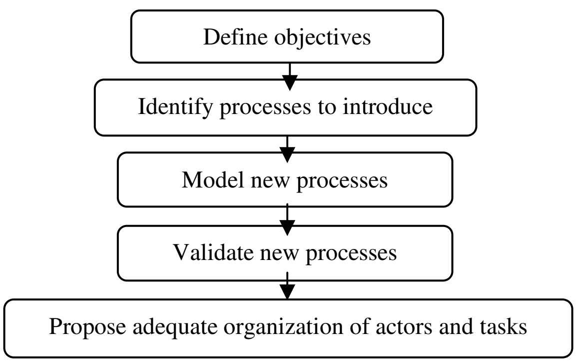

Fig. 1. Modeling of the BPR approach proposed to address the case of innovative processes

The proposed methodological contribution to this kind of processes is a method which is specific to innovative processes. It doesn't take into account the step of analyzing and understanding existing processes but goes directly to the identification of new processes to be introduced in the functioning of the company. This approach is represented in Figure 1 by a UML activity diagram.

Some examples of processes lying in this situation are: the process of tutoring in distance education [8] [9], that of collaborative learning in distance education [10], that of instructional design and online courses development [11], but also processes of telemedicine [12]. In this paper, we are more precisely interested in this last category of processes.

3 Telemedicine Case Studies for Innovative Processes Reengineering Projects

Technological developments in communication industry revolutionize the relationship between individuals and communities. This is the case of telemedicine. More specifically, the advent of ICT can give new ways to practice medicine and provide specialized medical services in areas that until now were disadvantaged. Telemedicine is the electronic transfer of medical data including sound, static or dynamic images and text in real time or offline for practicing telemedicine, to increase scientific and clinical exchange, and facilitate access to expertise. It allows professionals to communicate more while avoiding the constraints of time and space. Telemedicine essentially includes five processes: tele-consultation, tele-monitoring, tele-training, Tele-staff and tele-radiology [13] [14].

Reengineering projects related to telemedicine processes were treated in a rather particular way. We present below some of the case studies considered in this context, outlining approaches that have been considered for their reengineering. Processes considered in this paper are: process of teleradiology and tele-consultation.

These case studies allowed us to draw a number of deductions. We present below first the case of tele-radiology and then that of tele-consultation.

3.1 The Case of Tele-radiology

The process considered in this case study is tele-radiology process which is a medical procedure that covers two types of situations [15]:

- Tele-diagnosis that allows a local non-radiologist doctor to obtain the interpretation of an imaging examination,
- Tele-expertise that enables the exchange of opinions between two radiologists.

Two approaches have been experimented to ensure the reengineering of these tele-radiology processes:

- Define the objectives of existing medical activities, understand the old processes (radiology, diagnosis, expertise exchange, etc.), diagnose them and finally propose new processes.
- Define the objectives of tele-radiology, provide corresponding models of processes and then verify and validate these new models. This last step required several iterations until the new models have been validated. The obtained model concerning tele-diagnosis in the context of tele-radiology process is presented in figure 2.

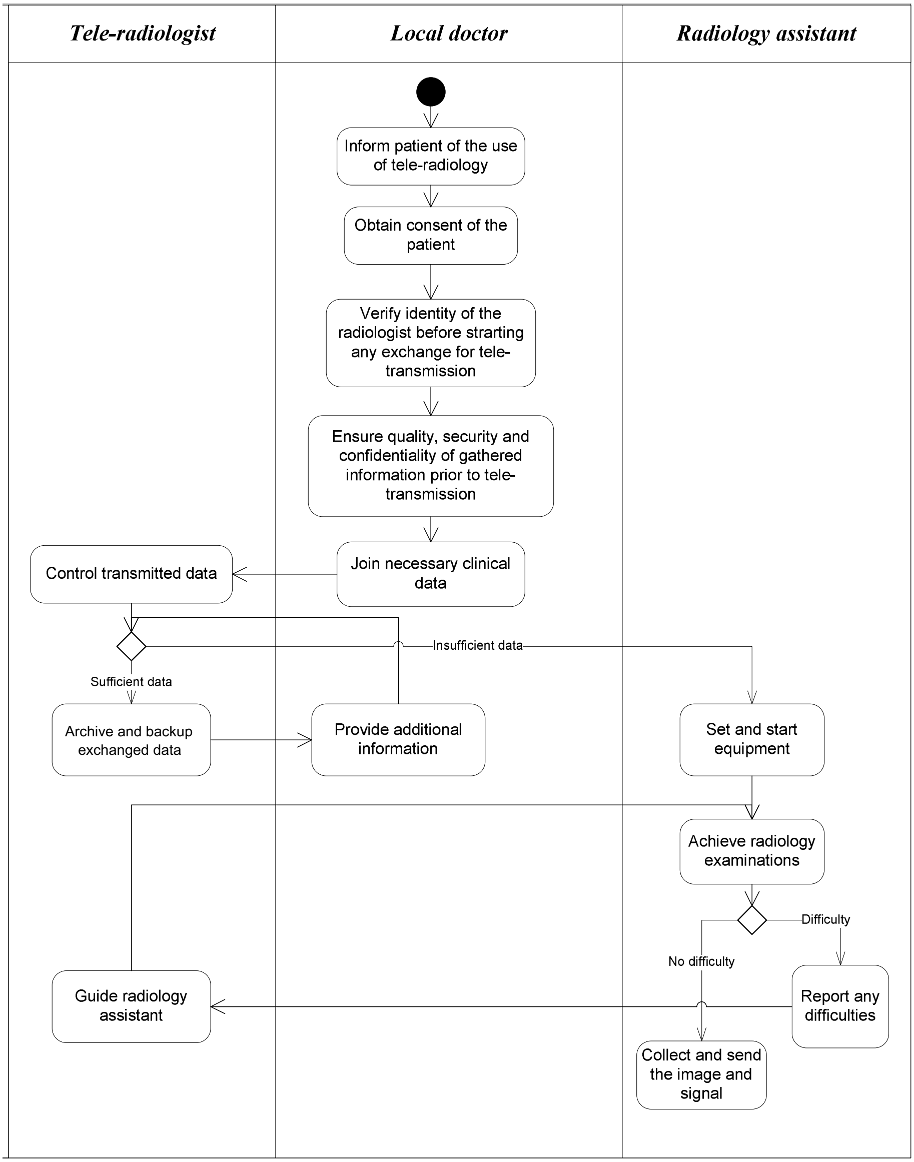

Fig. 2. UML Activity Diagram of tele-radiology process

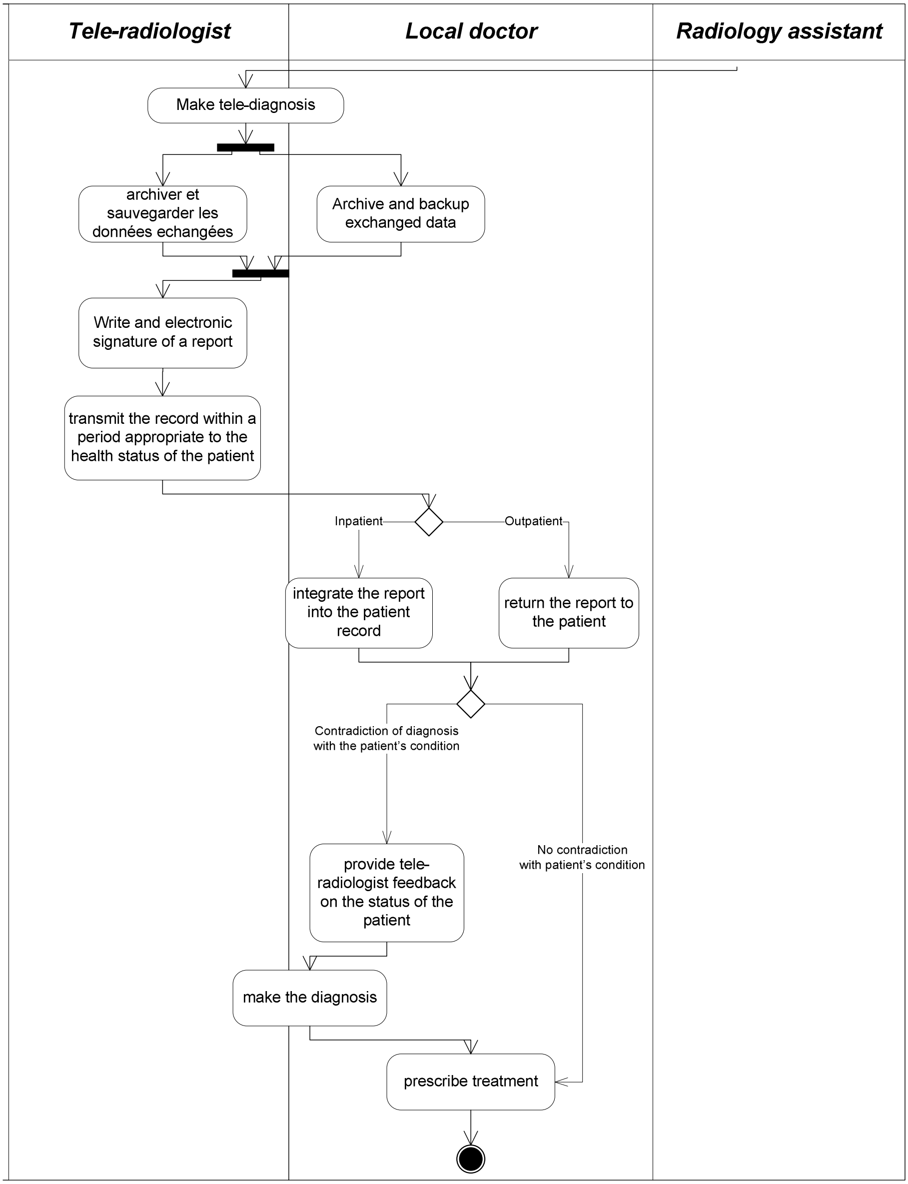

Fig. 2. (*Continued*)

3.2 The Case of Tele-consultation

The process considered in this case study is tele-consultation which is the assessment of the state of health or data of a patient via a telecommunication system, without direct physical interaction. It includes requests for opinions from a colleague, organization of emergency care, referral of a patient and arrangement of a possible transfer... [16].

Transmission of data can be done either in a synchronous or asynchronous way. There are two main types of tele-consultations [16]:

- A patient consults a doctor via a telecommunications network,
- The local doctor is seeking the opinion of another remote practitioner.

Two approaches have been also experimented to ensure the reengineering of tele-consultation processes:

- Define the objectives of medical activities, understand the former processes of consultation (patient-doctor consultation or doctor-doctor consultation), diagnose them and finally propose new processes.
- Define the objectives of tele-consultation, propose corresponding models of processes and then verify and validate these models. This last step required in this case study also several iterations until the new models have been validated. The obtained model concerning tele-consultation process taking place between a local and a distant doctor is presented in figure 3.

4 Deductions

We conclude that "innovative" processes where people and businesses had not yet time to develop traditions and habits can be addressed in two ways, through which models of these processes could be integrated into the functioning of a business. The first way consists in studying the existing processes, diagnosing them and then proposing the corresponding "e-processes" or new ways of working. The second way consists in directly studying new processes directly via the steps presented in figure 1.

This second way was considered in our experiments as the most appropriate. In fact, it has been adopted in both cases, since it was considered as the most efficient and there was less waste of time than in the first way of working. More generally, we believe that it is better adapted to the case of innovative processes as they require no prior detailed consideration of old processes which are very different from the new ones.

More generally, processes for which we actually applied this Methodology for Introducing Innovative Business Processes are the following:

- The processes of e-learning including tutoring in distance education [8] [9], collaborative learning in distance education [10] and instructional design and implementation of online courses [11].
- The processes of telemedicine [12], from which tele-radiology and tele-consultation processes are dealt with in this paper.

Models that have been designed for the different previously presented processes are in fact coherent with the idea of introducing new processes without necessitating to go deeper in understanding their previous way of working. In fact, innovating aspects appear as objectives of the project. Such innovating aspects are expressed through the new concepts to be introduced such as new rules or new technologies to be introduced. The completion of the BPR project leads to a new organization of actors and tasks.

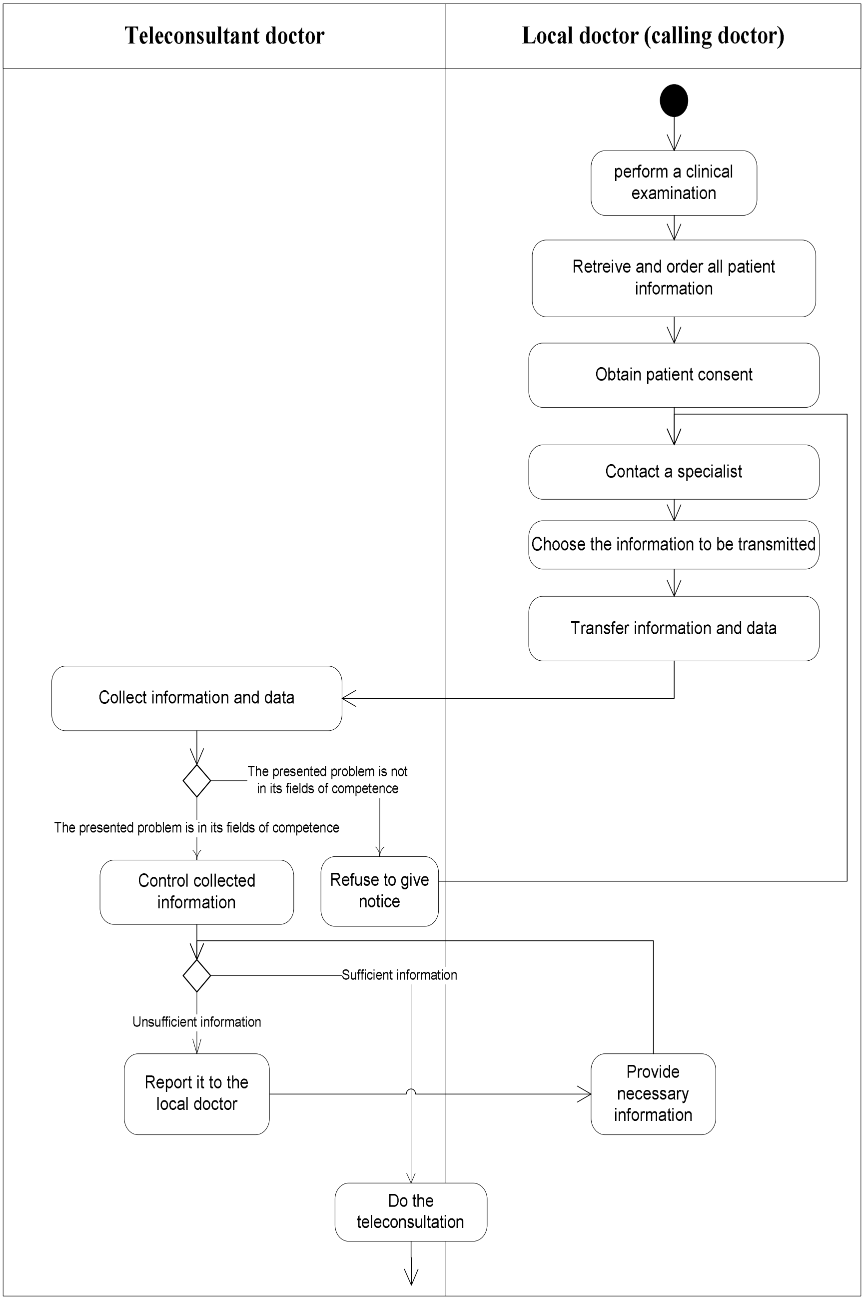

Fig. 3. UML Activity Diagram of the tele-consultation process

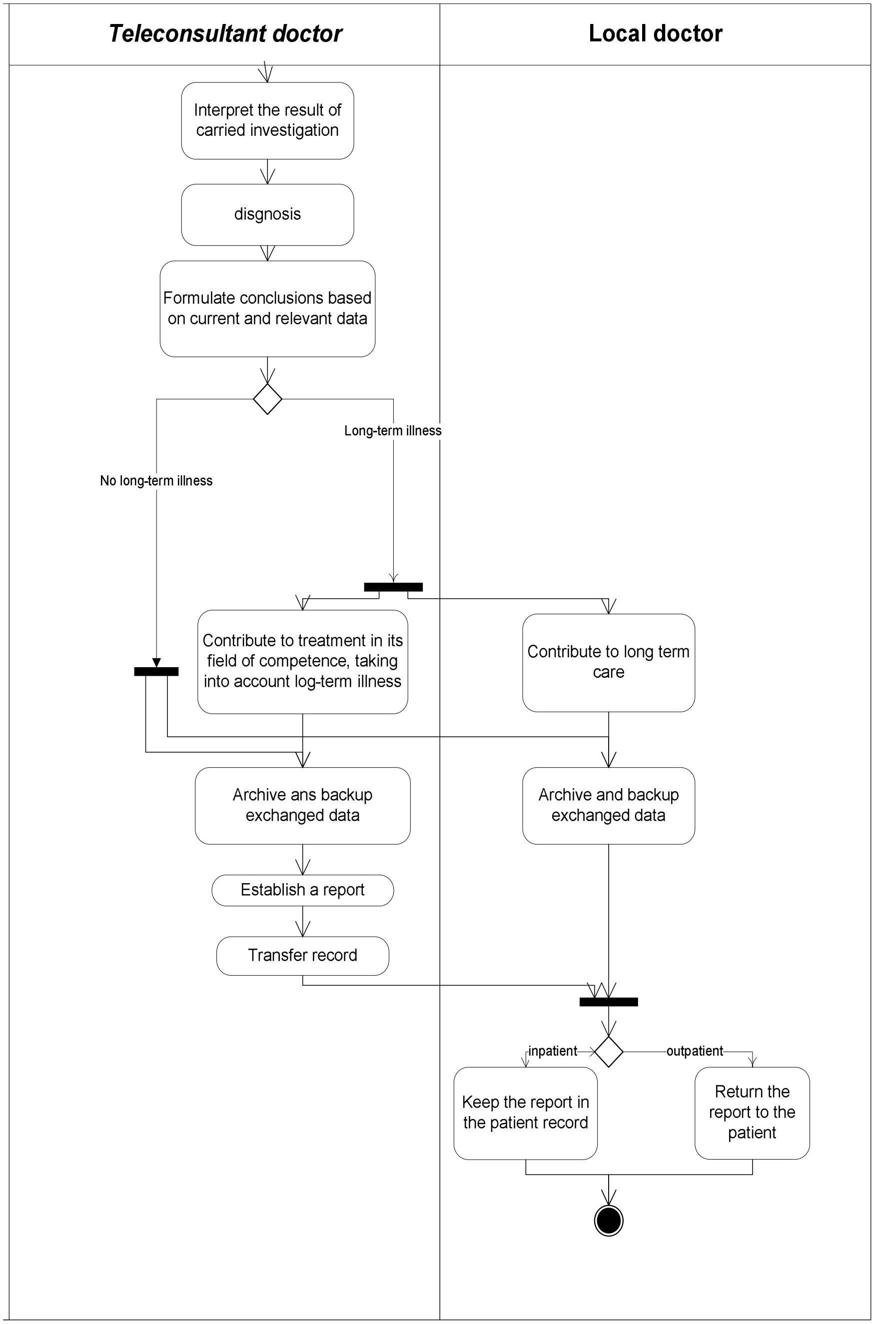

Fig. 3. (*Continued*)

5 Conclusion and Future Work

BPR (Business Process Reengineering) which is defined as the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical contemporary measures of performance, such as cost, quality, service, and speed, is considered in this paper with the special case of considering Innovative processes.

More precisely, we proposed in this paper a specific methodology for introducing innovative processes.

In order to validate this proposed methodology, case studies were considered. Those presented in this paper are in the field of telemedicine.

Our case studies in telemedicine gave results that confirmed the adequacy of the specific proposed methodology to the considered cases and consequently to introducing innovative processes.

This work is still open to a number of future works. In fact, in the field of telemedicine, more effort still has to be done in order to improve the gap between urban and rural telemedicine. In this context, multiple innovating technologies have to be tested and their potential influence has to be assessed [17]. The way in which such technologies can improve the quality, safety, efficiency, and effectiveness of health care still has to be studied [18].

Another future work will concern the proposition of a meta-model for innovative business process reengineering, including all involved concepts. This will allow a better understanding, assistance in modeling and will give more precise recommendations related to the way of reengineering concerned processes.

Moreover, a specific environment for introducing innovative processes in enterprise functioning will be designed and developed. This environment would be very helpful for guiding modelers and work teams involved in reengineering projects concerned with innovative processes.

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3D Semantic Models for Dental Education

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Abstract. This paper explores the benefits of using immersive and interactive virtual reality environments to teach Dentistry. We present a tool for educators to manipulate and edit virtual models. One of the main contributions is that multimedia information can be semantically associated with parts of the model, through an ontology, enriching the experience; for example, videos can be linked to each tooth demonstrating how to extract them. The use of semantic information gives a greater flexibility to the models, since filters can be applied to create temporary models that show subsets of the original data in a human friendly way. We also explain how the software was written to run in arbitrary multi-projection environments.

Keywords: Dentistry, Virtual Reality, Semantic Model.

1 Introduction

We noticed the need for a tool for interactive and intuitive communication between students and educators. This work proposes an educational tool for Dentistry, in specific for teaching basic dental anatomy.

This tool comprises a virtual model editor that allows the teacher to create, edit and visualize virtual models related to Dentistry. Complex virtual models can be reused to build new models for particular lectures.

There is a growing trend to aggregate semantic content to information, such as in the Semantic Web proposal. Semantic content, in this sense, means annotating data in such a way that it can be interpreted by both humans and computers.

The use of semantic descriptions, combined with virtual models, gives educators the possibility to generate content for their lectures with more relevant information. In order to increase the amount of information available to students, we can add multimedia content to the virtual models. Therefore we can have virtual classrooms

M.M. Cruz-Cunha et al. (Eds.): CENTERIS 2011, Part III, CCIS 221, pp. 89–96, 2011.

using 3D models with visual, textual and multimedia associate content relevant to the subject being taught.

This paper is organized as follows: we present what is semantic information and how it is implemented; then we present Virtual Reality (VR) and how it can be applied to Dentistry. Finally we present the tool itself and our conclusions.

2 Semantic Description of Virtual Models

The idea of aggregating semantic data to information has gained momentum with the advent of Semantic Web. It is defined in [1] as an extension of the World Wide Web, in which information is tagged so that humans can read or view it, but computers can also process it, making inferences and links to other information automatically. In this sense, the Semantic Web is a vision: the idea of having data on the web defined and linked together not only for presentation, but also for automation, integration and reuse between applications.

In order to achieve this, data must be described in certain formats, aiding machines to grasp its meaning. For example, when describing time on web pages, HTML 5 allows it to be tagged in way that allows computers to parse it easily: <time datetime="2009-10-22" pubdate>October 22, 2009</time>. The data between "< >" is not presented to the human reader, but what was to computers a simple list of characters ("October 22, 2009") can now be easily parsed by them, enabling queries that are more complex than pure text, e.g., "all events that happened on October 22, 2009 in Europe". There are many standards and languages recommended by W3C that are being used to index and infer semantic in applications.

The need to aggregate semantic content to virtual models can now be clearly grasped. Virtual models are usually just a list of geometric primitives, such as triangles, in 3D space. Computers can render images from these primitives through standard algorithms, but the original model and the final image have no information that certain part is a tree and another part is a car. It is difficult or impossible to manipulate the models in meaningful ways, and indeed large parts of 3D engines (libraries responsible for rendering the models into images) are devoted to managing 3D data.

This motivates our use of semantic information in the tool. We are not interested merely in showing 3D models of dental arcades: we want to provide interaction and powerful ways to annotate them. Semantic annotations make it possible for the user to specify only canines to be shown, or to search the model database for models with specific decays or abnormalities. It also allows to link information to data, e.g., a video showing an extraction to a particular tooth or X-ray images.

Ontologies have been used in Artificial Intelligence, helping in knowledge management, referring to concepts and terms that describe some area of knowledge or build a representation. In this work, an ontology is used to define dental properties.

RDF [2] defines mechanisms to associate properties to certain resources. A resource in RDF is any object that can be identified by a URI (Uniform Resource Identifier), for example, a document containing a project available at a website. This object can be associated with a property "Number of roots" to a node processing the

3D model, representing the amount of roots that the node can have: one, two or three. Since the type of tooth is "Canines", it has just one root. Each property value assigned to a resource is transformed into a triplet Resource-Property-Value. The triplet is the basis for establishing a data model in RDF. Such a model can be read as: "The amount of roots of canines in the http://wwwp.fc.unesp.br/lstr/Structure.x3d document is one".

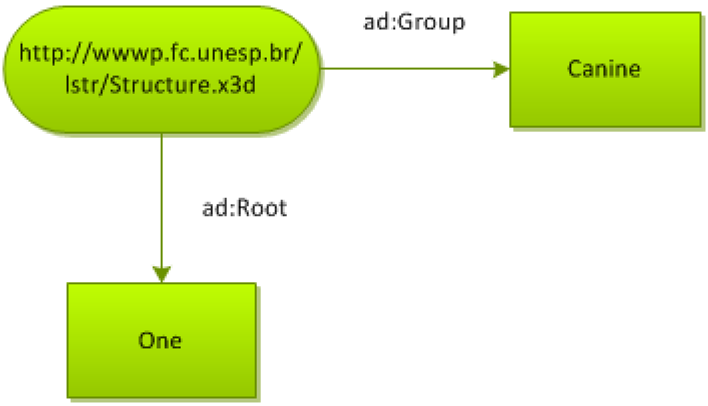

Fig. 1. Graph representing a RDF triplet

3 Virtual Reality and Dentistry

VR can be defined as a dynamic composition and reactive with the virtual environment created by computer and used for different modes of human interaction [3]. In VR one can interact in immersive environments generated by the computer in real time, manipulating the objects freely. The computer performs simulations to respond to user input, altering the virtual environment correspondingly.

VR is used in many applications, including formation and training of professionals, particularly in fields where it is costly, risky or unethical to perform procedures; the classical examples are airplane pilots and, most recently, medical procedures. Immersive VR environments use multiple screens to engulf the user, in such a way that all or most of his field of view is covered by the virtual images, to give the impression that he is inside the virtual model. Stereoscopic (3D) screens are often used. It's easy to see that VR is highly engaging, making students pay more attention, since they are interactive and use spatial reasoning (increasing retention and comprehension). Most VR applications are controlled by computer interfaces more natural than keyboard and mouse, such as gloves, joysticks and camera-capture gestures.

There is previous research on the use of VR on Dentistry. Most of the papers are concerned with tools for simulation, however.

Jasinevicius et al. [4] proposed an avaliation between two kinds of simulation applied to students of areas related to Dentistry, one based on VR and other on traditional methods. The purpose was to compare the efficiency of these two methods in regards to quality of learning and time used by the students, and the conclusion was that VR improved both.

Buchanan [5] developed a simulator for restoratives procedures. Developed at the University of Pennsylvania, School of Dental Medicine (UPSDM), it was one of the first simulations of this kind.

Steinberg et al. [6] proposed a tool for surgery training using haptic devices. Two screens are used, one showing the virtual environment and the other the informations for the surgery. Stereoscopy was used.

The combination of VR and semantic data allowed us to create a tool that not only explores the best features of VR systems, with its immersive and interactive features, but also integrates data in a useful and meaningful format.

4 Application

The application runs both on desktop PCs and on clusters. It has a simple graphical user interface, with the following functionality: open the 3D model; edit the model; describe it semantically; associate it to other media; run on the cluster for an immersive environment.

The 3D model is stored in X3D [7] format, which allows individual objects and transformations in separate nodes. This makes it easy to separate parts of the model for annotation or for creating new models. Several virtual models can be opened concurrently. Fig. 2 presents the application with a loaded model.

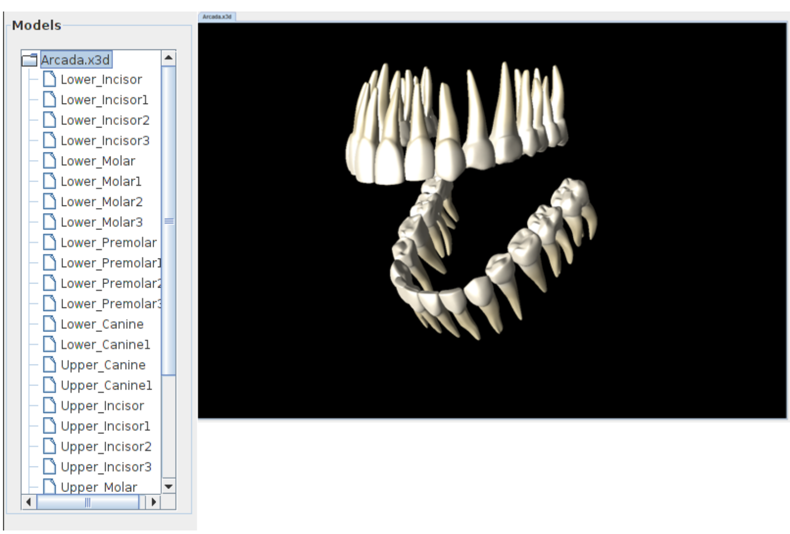

Fig. 2. Application interface

4.1 Semantic Description Module

The semantic description module uses an ontology to describe the associated information. As we mentioned previously, this allows the teacher to enrich the model with textual and multimedia information. The multimedia aggregations are performed using Dublin Core attributes: title, description, source and type.

The basic ontology for dental arcades is shown below, in Fig. 3. The ontology developed is present at http://wwwp.fc.unesp.br/lstr/Dental.rdfs.

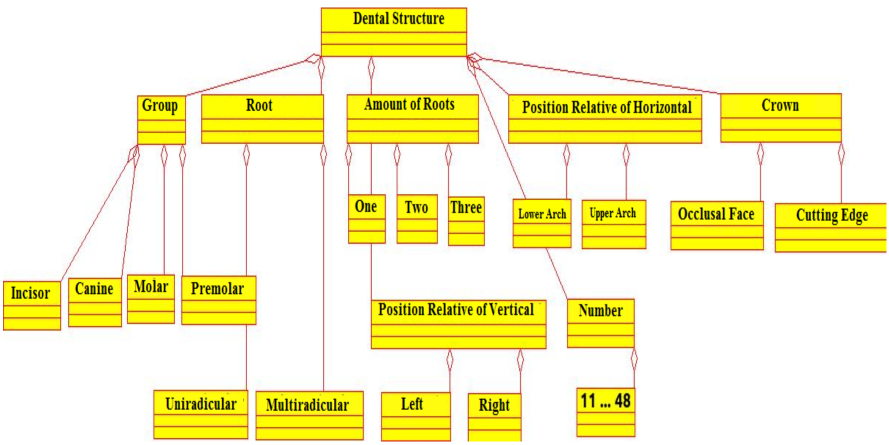

Fig. 3. Structure of the proposed ontology

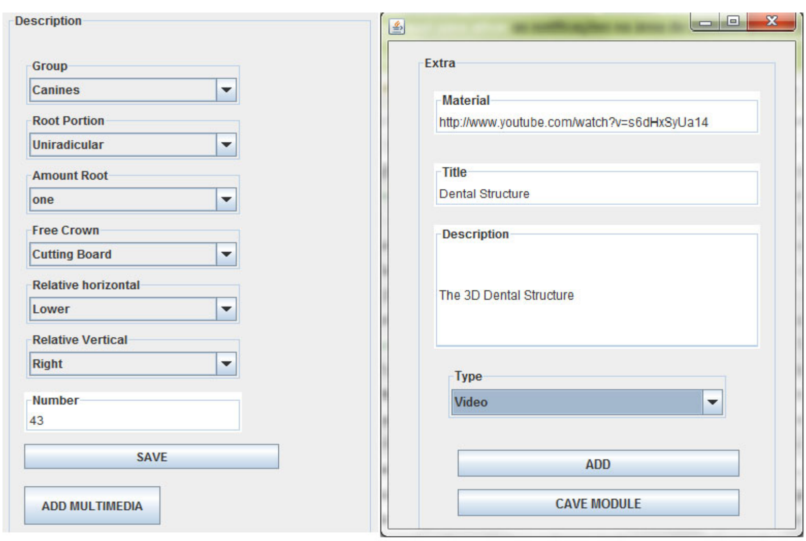

Fig. 4. Description of the sub model for canines and content aggregation

Data can be associated to multiple nodes, which are selected from the list. The attributes are automatically generated from the ontology and presented in fields for the user to fill. Fig. 4 shows a screenshot of one of these dialogs. We note some of the available fields, such as the number of tooth roots, relative position (horizontal and vertical) etc. The dialog for content aggregation (such as multimedia data) is also shown.

The code below presents a RDF document that has a virtual model described semantically. The virtual model also has a multimedia document association.

```
<rdf:RDF
xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
xmlns:ad="http://wwwp.fc.unesp.br/lstr/#"
xmlns:dc="http://purl.oclc.org/dc/#">
<rdf:Description
rdf:about="http://wwwp.fc.unesp.br/lstr/Lower_Canine.x3
d">
<ad:number>43</ad:number>
<ad:group>Canine</ad:group>
<ad:root>Uniradicular</ad:root>
<ad:amount_root>1</ad:amount_root>
 <ad:crown>Cutting Edge</ad:crown>
<ad:pos_horizontal>Lower</ad:pos_horizontal>
<ad:pos_vertical>Right</ad:pos_vertical>
 <dc:title>Dentistry Structure</dc:title>
<dc:description>Video about Dentistry
Structure</dc:description>
<dc:source>http://wwwp.fc.unesp.br/lstr/Arcada.avi</dc:
source>
<dc:type>Video</dc:type>
</rdf:Description> </rdf:RDF>
```

4.2 Mini CAVE

To enhance the immersion of educators and students, we implemented our tool in a mini CAVE. CAVEs [9] are immersive environments that surround the user with multiple screens for VR applications.

The structure is composed of three screens, high definition projectors, polarized stereoscopy (3D) and Wiimotes for control. Images are rendered in real time by a computer cluster. We note that, since we have three screens in stereoscopy, we need to render six images for each frame. Fig. 5 shows our setup.

In order to be easy to use, we control the entire system through an extended graphical user interface. No special knowledge is required from the users, who only have to load the models as in the desktop version.

The multiple screens can be arranged to show not only the model itself, but also multimedia data associated to it, particularly videos, as shown in Fig. 6.

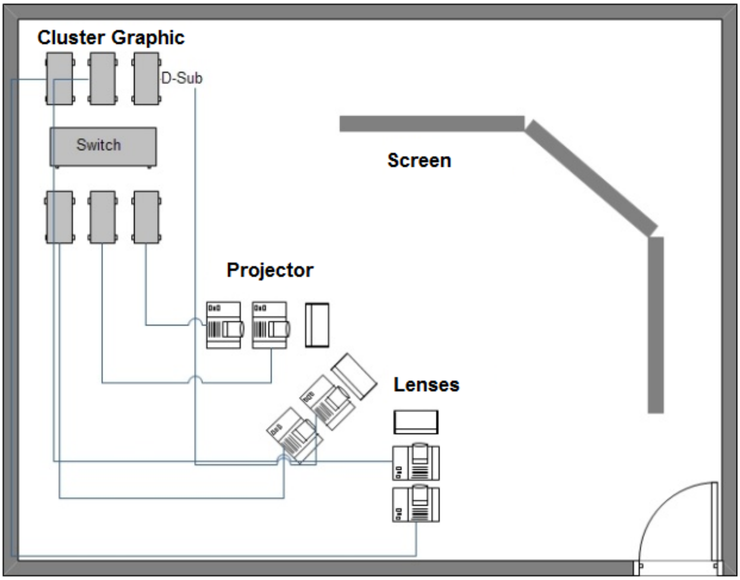

Fig. 5. Physical setup of our CAVE

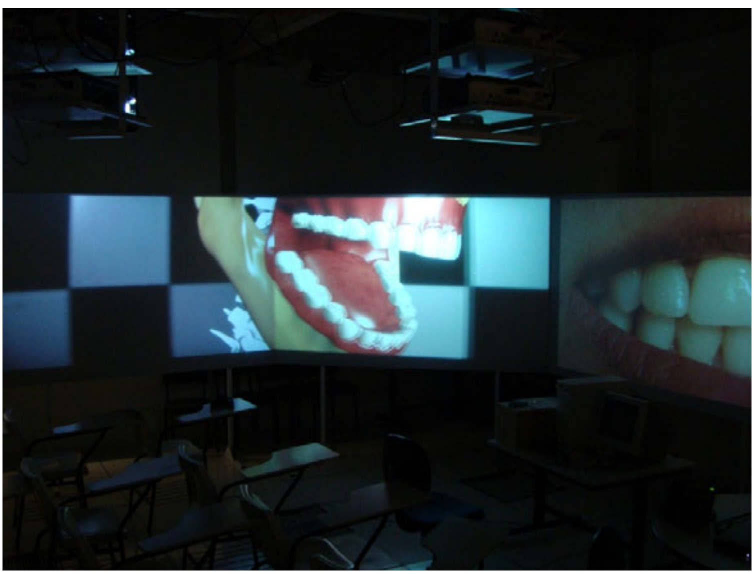

Fig. 6. Mini CAVE running our tool. Two screens are showing the 3D model, and a third is showing a video linked semantically to it.

5 Conclusions

The tool developed in this project was deemed interesting by educators. Its combination of VR and Semantic data led to a system that is at the same time easy and natural to use, but contains a lot extra of information that can be accessed on demand. The system can run on single PCs or in interactive VR environments, such as the mini CAVE presented.

The tool is currently limited only by its database. More detailed 3D models are planned and can be easily tagged with new attributes, extending the proposed ontology as necessary.

We also have implemented a web version that can be used to visualize the semantic models in a web browser. Therefore students can access it at any time, studying even if they are not at a VR laboratory.

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Evaluation of the Inter-observer Cardiac Chamber Contour Extraction versus a Level Set Algorithm

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Abstract. Segmentation of echocardiography images presents a great challenge because these images contain strong speckle noise and artifacts. Besides, most ultrasound segmentation methods are semi-automatic, requiring initial contour to be manually identified in the images. In this work, a level set algorithm based on the phase symmetry approach and on a new logarithmic based stopping function is used to extract simultaneously the four heart cavities in a fully automatic way. Then, those contours are compared with the ones obtained by four physicians to evaluate the performance, reliability and confidence for eventual clinical practice. That algorithm evaluation versus clinicians' performance is made using several metrics, namely Similarity Region, Hausdorff distance, Accuracy, Overlap, Sensitivity, and Specificity. We show that the proposed algorithm performs well, producing contours very similar to the physicians' ones with the advantage of being an automatic segmentation technique. The experimental work was based on echocardiography images of children.

Keywords: heart segmentation, echocardiographic images, phase symmetry, level set, similarity index.

1 Introduction

Medical ultrasonography is an important tool for imaging the heart structures, since it is noninvasive, safe, portable, and the images are available in real-time and the cost is low compared to other medical imaging techniques [1, 2]. Another reason for its success is that the information it provides is very helpful in clinical diagnosis of heart diseases, and also in emerging areas such as image-guided interventions [3, 4]. Anatomical quantitative information about the heart chambers is crucial for clinicians, namely wall motion, valves function, and volume estimation.

Today, most of the used methods are still semi-automatic requiring human interactivity to select the correct region of interest (ROI) [5-7]. Fully automatic segmentation [8] can reduce this intra-expert variability and provide clinical valuable information about the cardiac cavities and their respective volumes, working also as an important

M.M. Cruz-Cunha et al. (Eds.): CENTERIS 2011, Part III, CCIS 221, pp. 97–106, 2011.

step to achieve 3D heart reconstruction, which quality is greatly influenced by the segmentation accuracy. Most recent segmentation methods based in deformable models, as parametric models or geometric models including level-set, are used to identify not only heart regions [9-11], but also lungs [12-18], vascular or neural structures[19] and to assist the classification of pathologies [20, 21].

Active contours have been used for image segmentation and boundary tracking since the first introduction of snakes by Kass [22]. The basic idea is to start with initial boundary shapes represented in a form of closed curves, i.e. contours, and iteratively modify them by applying shrink/expansion operations according to the constraints of the image. Methods to accomplish those operations were introduced by Kass [22], and then reformulated in the context of partial differential equations [23] (PDE) by Caselles [24] using the level set framework.ï

Geometric active contour model was the first level set implemented active contour model for the image segmentation problem. It was simultaneously proposed by Caselles [24] and by Malladi [25]. This model is based on the theory of curve evolution and geometric flows. The geodesic active contour model proposed by Caselles [24] allows connecting classical "snakes" based on energy minimization and geometric active contours based on the theory of curve evolution. In order to improve the segmentation performance, the integration of edge and region based information sources using active contours has been proposed by a few authors. Paragios [26] proposed the geodesic active region model for supervised segmentation, integrating edge and region-based in an energy function. Zhang [27] also apply this association to achieve robust and accurate segmentation results. He tried to solve the problem from a more geometric perspective, describing the advantages of the model over Chan method [28] on medical images with complex backgrounds.

The use of level set theory has provided more flexibility and convenience in the implementation of active contours. Depending on the implementation scheme, active contours can use various properties used for other segmentation methods such as edges, statistics, and texture. In the present work, we describe the segmentation method based on level set that is capable to identify simultaneously the four heart chambers. The used phase symmetry approach, which acts in the frequency domain extracting low level features, is of great importance for the success of the algorithm [9, 10, 29]. The segmentation results are compared with those provided by the reference contours provided by four physicians, using several metrics of similarity.

The outline of the paper is as follows. In section 2, we describe the segmentation method and the metrics used for the evaluation. Then, the algorithms are applied to children echocardiographic images. The results and discussion are presented in section 3, and finally, the conclusions are formulated in section 4.

2 Methodology

2.1 Overview of the Segmentation Algorithm

The applied segmentation algorithm is composed by several phases. First, low-level features are extracted from the collected images (see figure 1) using a Phase-based Symmetry Detection, a procedure based on gradient/luminance information and on Log

Gabor wavelet by finding symmetric or partial symmetric components in the frequency space, allowing the enhancement of shapes in the images (see figure 1b) [29].

Second, a modified level set is used that minimizes the function by solving the correspondent partial differential equation. A higher dimensional function $\phi(x,t)$ is manipulated to evolve a contour (or surface) implicitly, where the zero level is used to extract the evolving contour $C = \{x \mid \phi(x) = 0\}$.

$$\frac{\partial \phi}{\partial t} = |\nabla \phi| \left[div \left(\frac{\nabla \phi}{\nabla \phi} \right) + v \right] P \tag{1}$$

The initial function ϕ_0 is a mask based on the Euclidean distance, where the central pixel has the biggest value and the remaining pixels decrease towards zero till they meet the image limits. Then, the function is updated at each iteration, based on shrink and expansion operations depending of the level set curvature and the stopping function P.

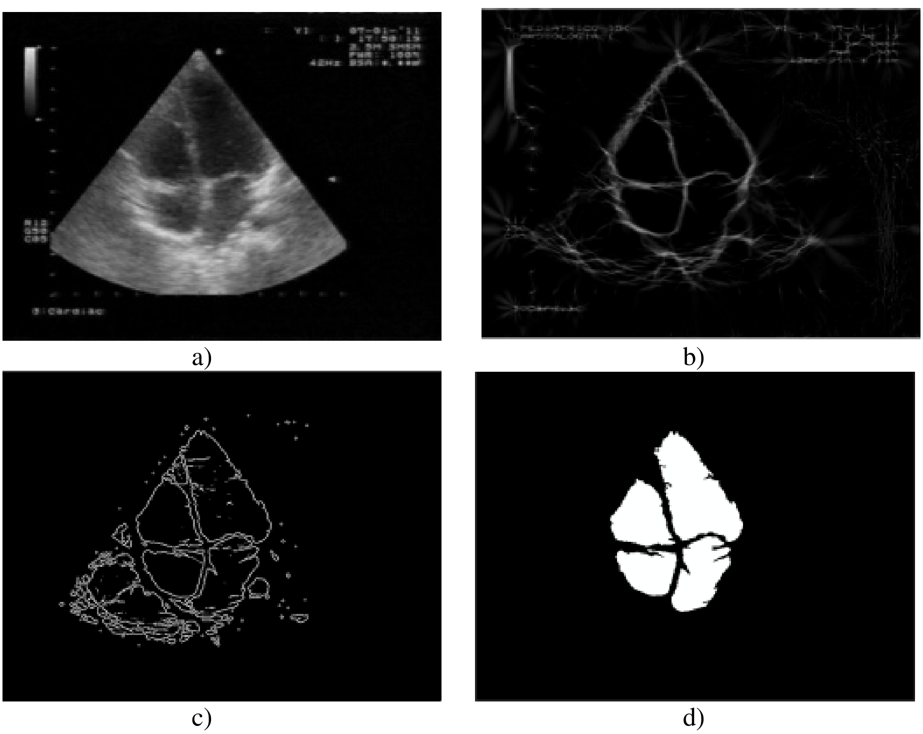

Fig. 1. Segmentation method: (a) original Image, (b) detecting low-level features, (c) applying the segmentation method, (d) post-processing

The stopping function P is represented by:

$$P = \log \left(\left| \frac{I - \varepsilon}{\gamma} \right| + 1 \right) \tag{2}$$

where is the average intensity value of the image I and is the dynamic range of the region being analyzed. This stopping function of logarithmic variation performs adjustments to the regions in study until the convergence is reached. This happens after few iterations. The segmentation result is illustrated in figure 1c.

The last step consists in the post-processing, where all the smaller regions detected are removed by using morphological operations in order to obtain smoothed contours.

2.2 Validation Metrics

To evaluate the performance of the segmentation algorithm, we compare the extracted contours with the reference contours drawn by some physicians. For that goal the following six metrics are used.

Similarity Region (SR) is based on the difference between two regions [30, 31].

$$SR = 2\,\frac{A\,.\,B}{A\,+\,B} \tag{3}$$

The Similarity Region varies from zero to one where the value ‘0’ corresponds to the total dissimilarity of the two regions, and the value ‘1’ to the exact overlapping.

Hausdorff Distance (h) defines a distance between two given curves (A and B). Whenever an overlap between them occurs that distance is zero, otherwise the distance from each point in A to all points in B [32, 33] is calculated, and the smallest value is kept. Finally, the highest value is searched from the collected set of distances.

$$h(A,B) = \max_{a \in A}\ \{\ \min_{b \in B}\{\ d(a,b)\ \}\ \} \tag{4}$$

The Hausdorff Distance does not have a defined variation range as the other metrics; the minimal and best value is zero (contours overlapping).

Accuracy, Overlap, Sensitivity, Specificity: These four measures are based on the relation between two regions defined by two contours A and B [34]. The pixels of both regions are classified as: N_{TP} = pixels present in both regions; N_{TN} = pixels absent in both regions; N_{FP} = pixels present in B, absent in A; N_{FN} = Pixels present in A, absent in B. Thus,

$$\text{Accuracy} = \frac{N_{TP} + N_{TN}}{N_{TP} + N_{TN} + N_{FP} + N_{FN}} \tag{5}$$

$$\text{Overlap} = \frac{N_{TP}}{N_{TP} + N_{FP} + N_{FN}} \tag{6}$$

$$\text{Sensitivity} = \frac{N_{TP}}{N_{TP} + N_{FN}} \tag{7}$$

$$\text{Specificity} = \frac{N_{TN}}{N_{TN} + N_{FP}} \tag{8}$$

Accuracy is the ratio of correctly classified points in the ROI; Overlap gives the amount of intersection between A and B; Sensitivity gives the information of the pixels that are correctly classified and belong to the contour; Specificity measures the proportion of pixels that are correctly classified as not belonging to the contour. All of these metrics have a range from zero to one, where one represents the optimal value.

2.3 Dataset

The data set has 240 cardiac chamber regions extracted from sixty images with a resolution of 768×576 pixels, selected from several children echocardiographic videos. The reference cavity contours drawn by the experts, were obtained with the help of a graphical interface, then minimizing the inherent error associated to hand drawn contours and the following necessary digitalization. Figure 2a-c illustrates the procedures for the references delineation.

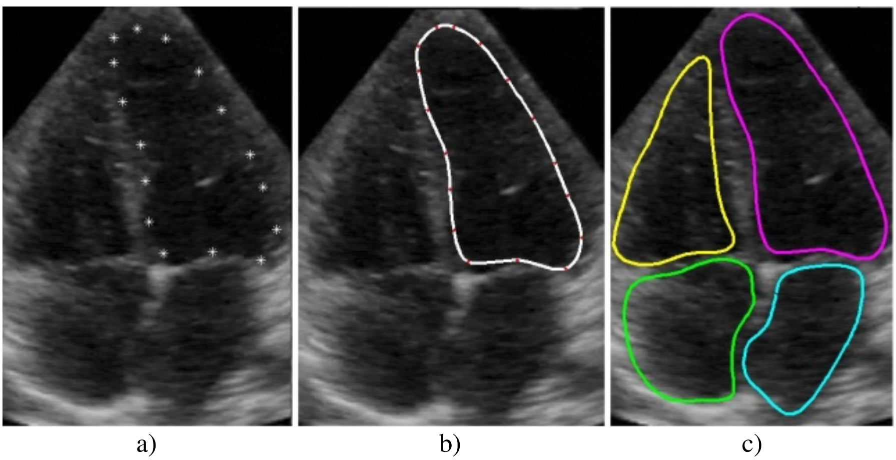

Fig. 2. Reference contours acquisition: (a) points defined by the user, (b) cubic spline interpolation, (c) four cavity contours used as reference

3 Results and Discussion

This work consists of the performance analysis of all extracted contours from the dataset by the proposed algorithm, and the reference contours drawn by physicians. For that, two distinct inter-observer comparisons will be defined, namely Algorithm vs. Physician and Physician vs. Physician.

3.1 Comparison between Contours

The performance evaluation of the algorithm versus clinicians was accomplished by using the metrics described previously.

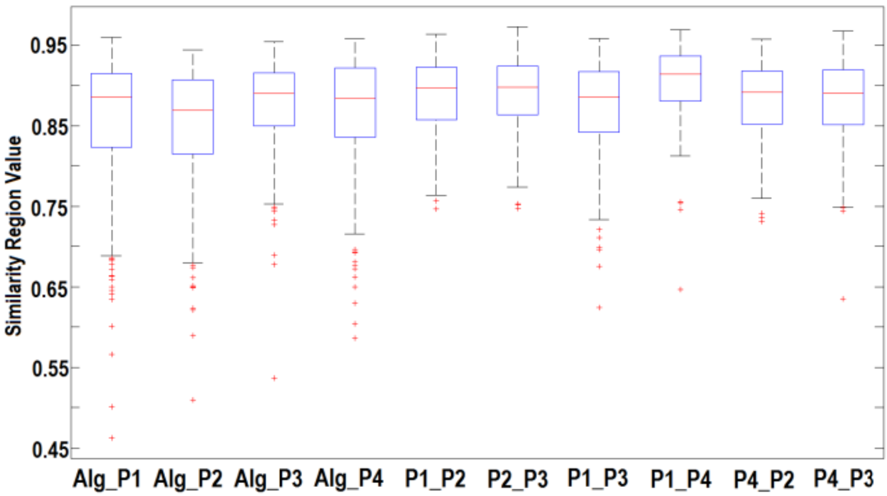

Fig. 3. Similarity Region Box-Plot Graphic: Alg - Algorithm; P1, P2, P3, P4 - four Physicians

Figure 3 shows the results for the Similarity Region metric. The median values for the first four columns that represent the Algorithm vs. Physician behavior are 0.89, 0.87, 0.89, and 0.88. The remaining median values are 0.90, 0.90, 0.89, 0.91, 0.89, 0.89 that are slightly superior to the previous ones, however the difference is very small (0.01 in average), then illustrating similar performances for the analyzed comparisons. It was also verified that the metrics Accuracy, Overlap, Sensitivity and Specificity show similar results.

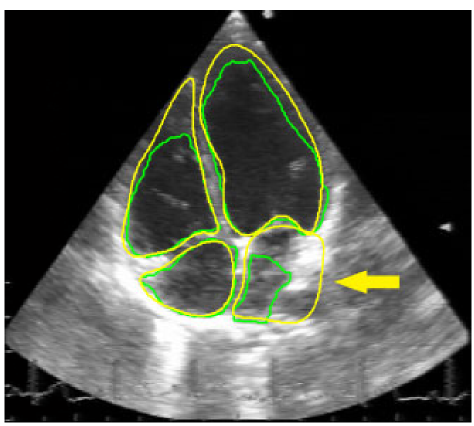

Fig. 4. Contour Outlier SR for Algorithm vs. Physician (Alg_P1)

From figure 3 it is observed the presence of a considerable number of outliers. In figure 4 it is depicted the worst outlier (Alg_P1) using the SR metric. The corresponding computed value was 0.46 dealing with the evaluation of the cavity identified by the arrow. This worst case is a result of the fact that the boundaries are not clearly defined for this cavity, due to the presence of an artifact. That motivated the physician to draw the cavity region according to his knowledge and experience.

3.2 Single Cavity Analysis

A single cavity comparative study was also accomplished. Figure 5 shows the results related to the Left Ventricle (LV) using the Hausdorf Distance. Again, two comparative approaches were considered: Algorithm vs. Physician (first 4 columns) so called as set A and Physicians vs. Physicians (last 6 columns) referred as set B.

The calculated median values in set A are 17, 17, 13, 21 while in set B those values are 19, 19, 20, 21, 20, 17. These results lead us to conclude that the extracted contours by the algorithm are closer to the physician´s ones than what is verified when the performance of an expert is compared with the other experts. Comparing the 25th percentile in the interquartile range for the set A (values: 14, 13, 17, 9) and the set B (values: 15, 16, 16, 19, 16, 14) it is observed that set A has lower values meaning lower error, then better performance than it is provided by of a physician, using as reference the others physicians.

Similar conclusions are obtained comparing the 75th Percentile of set A (values: 21, 20, 25, 15) and set B (values: 21, 22, 27, 27, 24, 25). From the analysis, it can be concluded that the interquartile ranges for Algorithm vs. Physician present normally smaller dispersions than it is verified for Physician vs. Physician.

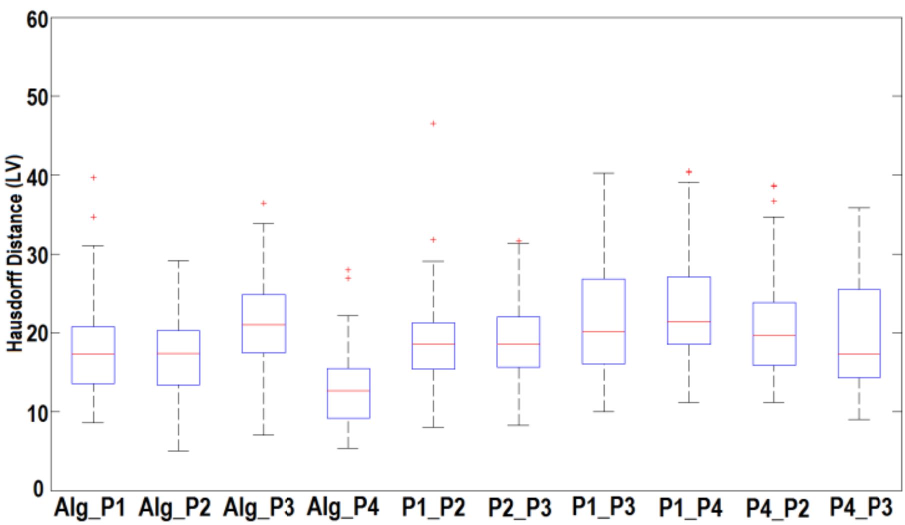

Fig. 5. Hausdorff Distance Box-Plot Graphic for Left Ventricle

The evaluation of the other heart cavities has led to similar results. Also, the same study was carried out for the metrics, Accuracy, Overlap, Sensitivity and Specificity, and the results agree with the ones produced by the Hausdorff metric.

4 Conclusions

Cardiac boundary extraction from echocardiographic images remains an important clinical challenge. We have proposed an improved algorithm for automatic contour extraction on apical long-axis four chamber view sequences of echocardiograms.

We tested the algorithm on a representative clinical dataset composed by two hundred and forty cavities and compared the results to contours manually sketched by four clinicians. That analysis was carried out by using some figures of merit, where the performances algorithm vs. physician and physician vs. physician were of concern.

It was observed that the algorithm provides results that are comparable to the inter-observer variability when the four cavities contour extraction are analyzed. Also, the algorithm performance is good when a single cavity is tested for algorithm vs. physician behavior, and presents superior results to the physician vs. physician achievements.

The positive results obtained with the present work, motivated the authors to proceed the development of new approaches for the simultaneous segmentation of the four cardiac chambers, thus assisting image-guided interventions and helping the experts in the clinical diagnosis, namely in the detection of congenital heart diseases.

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Requirements for Laser Doppler Imaging Modality Representation in DICOM

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Abstract. DICOM standard in its current state does not support Laser Doppler Imaging (LDI) modality. Based on experience in producing LDI devices at Aïmago SA we present requirements for the modality support in DICOM. This paper can be interesting to people who are responsible to maintain DICOM standard up to date with modern medical imaging techniques. The paper could also be of interest to manufacturers of LDI devices who would like to produce DICOM conformant LDI equipment.

Keywords: Laser Doppler Imaging, LDI, DICOM, requirements.

1 Introduction

This article will discuss the requirements for representing Laser Doppler Imaging modality using the DICOM standard. Current section will introduce to readers both Laser Doppler Imaging and DICOM. Section 2 of the article will explain the problem that exists with the current state of DICOM specifications. Section 3 will introduce our proposed approach to solution for the explained problem. Concluding remarks will indicate possibilities for a future evolution of this work.

1.1 Laser Doppler Imaging

Laser Doppler Imaging (LDI) is a medical imaging modality that allows producing images of perfusion of capillary blood flow. The underlying technology is based on Doppler Effect that was discovered by Christian Doppler in 1842 [2]. Due to this effect a shift in a wave frequency exists for an observer if the observer and the wave source are moving in relation to each other. In its application to the capillary blood flow Doppler shift is produced on red blood cells that move within the flow while they are illuminated by a medically non-invasive laser radiation. Based on the detected Doppler shift it is possible to characterize velocities of the blood cells moving within the flow.

Applications of Laser Doppler technology for monitoring of blood flow started from the use of Laser Doppler velocimetry by Riva et al. that was reported in 1972 [7]. Laser Doppler velocimetry used in medical applications became known as Laser

M.M. Cruz-Cunha et al. (Eds.): CENTERIS 2011, Part III, CCIS 221, pp. 107–116, 2011.

Doppler flowmetry. This method allowed monitoring perfusion of a single point on the skin illuminated by the laser beam, delivered either directly or through a fiber.

The next step in the technology evolution was the introduction of the scanning laser beam approach, first reported by Wårdell et al. [11] and shortly after that by Niazi et al. [6]. This allowed monitoring blood flows over an area rather than at a single point. It was an important improvement because it enabled construction of perfusion maps of observed area. Such maps were showing relative perfusion differences between the points on observed area. It was natural to present the perfusion maps in a human-friendly way as images, marking the points of different perfusion levels by their corresponding set of different colors. Thus the concept of Laser Doppler Imaging has emerged.

Since its introduction around 20 years ago, one important improvement in LDI technology happened in 2002, when Serov et al. [8] reported on the use of fast CMOS sensor for LDI. This allowed passing from the scanning laser beam approach to the full field perfusion imaging. While with the scanning approach it was necessary to spend minutes to produce a single perfusion image, with Serov's full field approach it became possible to produce real time LDI sequences. Over the years that passed since its introduction in 2002, the full field LDI technology has been gradually improved and its attainable speed of visualization has been significantly increased [3, 9, 10].

Currently both the scanning beam LDI and the full field LDI devices are available as medical products produced by the LDI manufacturing companies.

1.2 DICOM

DICOM stands for Digital Imaging and Communications in Medicine. It is a specification of data storage and communications rules that are useful for storing and transferring of medical images.

In a hospital environment there may exist a multitude of devices of different types that produce a rich variety of kinds of medical images. The goal of DICOM is to help achieving interoperability between such devices and hospital Information Systems. If all the devices have a standard way to connect to hospital Information Systems and to store their produced images, then such devices can be integrated within the same hospital workflow and the different images can be viewed by any viewer software that is conformant to the standard specifications. DICOM specifies this standard way of storing and transferring images, which facilitates significantly the management of medical images in a hospital. This is why DICOM became very popular in hospitals around the world.

As it was described by Bidgood and Horii [1], the history of DICOM started in 1982 when the American College of Radiology and National Electrical Manufacturers Association (NEMA) formed a committee to develop standards for interconnection of digital imaging devices. Three major versions of specifications have been published since that time. Starting from the version 3 that was released in 1993 the specifications are called DICOM. The latest to this date version of DICOM published by NEMA [4] is marked as 3-2009.

2 Problem: Missing Support for LDI Modality in DICOM

DICOM in its part related to media storage specifies how digital medical images and other digital medical documents must be encoded and stored. In particular, all elements within a DICOM file are grouped in conceptually meaningful groups and tagged with element tags. An element tag assigns two hexadecimal identifiers to its element: one of them characterizing the element's group number, and the other characterizing the element's number within the group. Such an identifier uniquely identifies an element within a DICOM file.

According to DICOM specifications any digital medical image file among other elements contains an element indicating imaging modality of original device that has produced the image. The element tag is (0008,0060). DICOM specifications [4] in the part 3.3 section C.7.3.1.1.1 introduce 55 kinds of modalities that conform to the current version of the specifications. LDI is not among these 55 modalities.

For each of the supported modalities DICOM specifies a class whose attributes correspond to the media storage needs of the modality. In DICOM such classes are called SOP classes and they are differentiated by their unique identifiers (UIDs). For example, SOP class for Ultrasound Image Storage that corresponds to Ultrasound modality has 1.2.840.10008.5.1.4.1.1.6.1 as its UID.

DICOM calls SOP class specifications as Information Object Definitions (IODs). IODs can be found in DICOM part 3.3. For each IOD the standard defines attributes that are necessary to represent a media storage instance of the corresponding SOP class. The attributes are grouped in modules. For example, IOD for the aforementioned Ultrasound Image Storage SOP class defines two modules (US Region Calibration Module and US Image Module) and over 90 dedicated attributes contained in these two modules. The dedicated attributes are specifically designed to store an image produced by a device of Ultrasonic modality.

Thus when a company that produces medical devices wants to store its medical images in DICOM, it selects from the list of supported 55 modalities its Modality element value for (0008,0060) tagged element, selects an SOP class that corresponds to the modality media storage and constructs its DICOM files in correspondence with IOD for the selected SOP class. This is the standard way of use of DICOM for storing medical images. Following this way guarantees interoperability between medical software packages that are produced by different manufacturers. For example, DICOM images created and stored with an equipment of one company will be possible to interpret and to view with DICOM-viewer software from another company.

As we have mentioned, currently Laser Doppler Imaging cannot be found among the modalities supported by DICOM. This prevents all manufacturers of LDI devices from using DICOM in the described standard way for storing LDI images. Thus currently it is not possible for different manufacturers to create interoperable DICOM-based solutions for LDI.

3 Solution: Approach to Support LDI Modality in DICOM

Previous section has identified one currently existing problem of DICOM standard that is the absence of support for LDI modality in DICOM. As we explained, the identified problem leads to impossibility of achieving interoperability for LDI within an environment that has devices and software packages originating from different manufacturers.

In this section the readers will see a possible approach towards integration of LDI modality in DICOM standard. The presented approach is based on our practical experience of manufacturing LDI medical devices at Aïmago SA.

Aïmago SA is a company producing real time full field LDI medical devices that enable in vivo assessment of blood flow in dermal tissues and skin. As it was reported in [3], Aïmago LDI devices allow for monitoring of the blood perfusion in an area of about 50 cm^2 with the resolution of 480 × 480 pixels per frame at a rate of 12–14 frames per second. Smaller frames can be monitored at much higher frame rates.

Thus Aïmago LDI devices produce real-time video sequences of LDI snapshots. This allows for capturing not only blood perfusion data at a moment in time, but also dynamic changes in patient's blood microcirculation that are due to different physiological effects (heartbeat, breathing, etc). Thus we need DICOM to support storage of sequences of LDI snapshots and their associated data.

At Aïmago each LDI snapshot consists of three images and their metadata. The three images are:

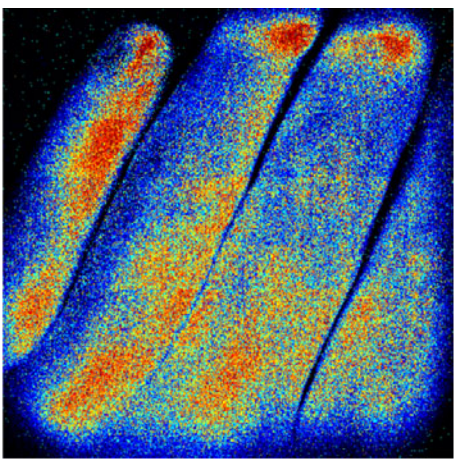

Fig. 1. Laser Doppler Image

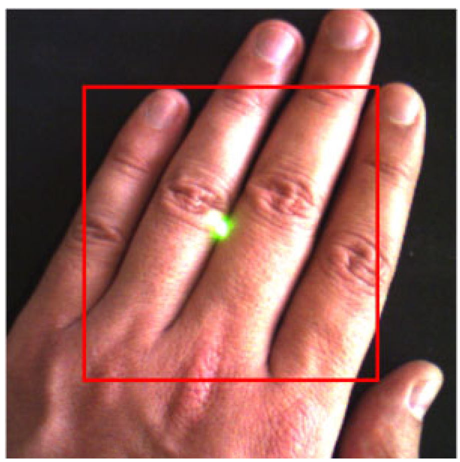

Fig. 2. Color image

- Laser Doppler Image – an image of an area of interest produced by LDI camera (see Figure 1 as an example).
- Color image – an image of the area of interest for Laser Doppler Image and of its bordering, surrounding area produced by regular color camera (e.g. see Figure 2).

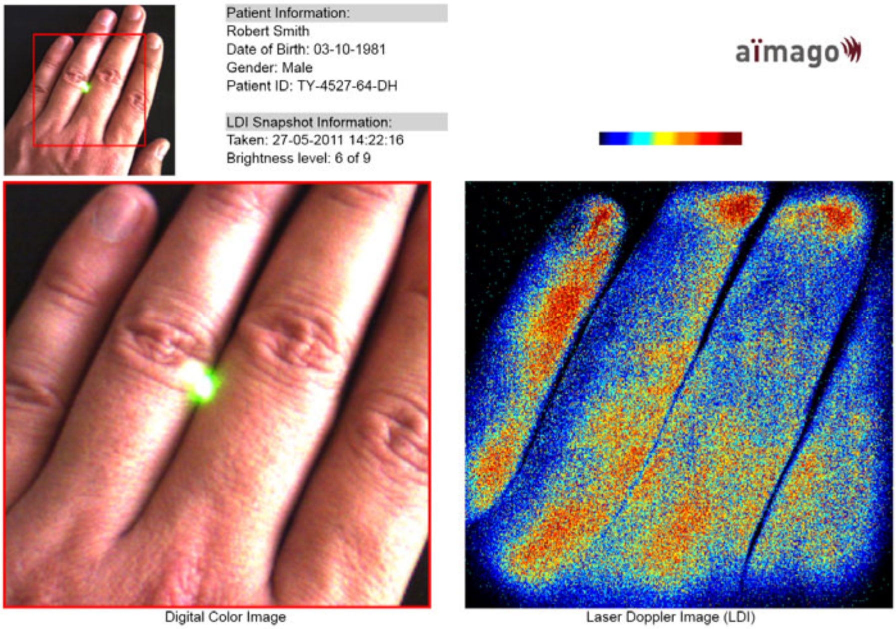

Fig. 3. Integral view image

- Integral view image – an image that presents an integral view of LDI snapshot based on some (or all) of data extracted from the Laser Doppler Image, the Color image and the metadata (see Figure 3 as an example).

Aïmago has a requirement from its customers to store LDI files in DICOM format in order to integrate Aïmago LDI devices into standard hospital workflows. How can we fulfill this requirement with no support for LDI modality in current version of DICOM? We decided to address this problem in two steps: the first – as a short term solution, the second – as a long term solution.

3.1 Short Term Solution: Use Existing SOP Class and Private Tags

One of the 55 modalities supported by DICOM is called "Other". Its Modality element value for (0008,0060) tagged element is OT. This modality does not have a particular associated IOD and does not assume any constraints for a selection of an SOP class to use for storing OT images.

As a short term solution for storing LDI files in DICOM we decided to use OT modality and one of existing SOP classes that is defined by DICOM for one of its supported (different from LDI) modalities. According to DICOM ([4] part 3 p.147) Secondary Capture (SC) Image IOD is used to specify images that are converted from a non-DICOM format to a modality independent DICOM format. Thus Multi-frame True Color Secondary Capture Image IOD with UID 1.2.840.10008.5.1.4.1.1.7.4 was found to be the most convenient for our needs. Attributes of this class are not bound to a particular image origin and support storing of sequences of images.

We use this class to store most significant parts of our LDI snapshots (i.e. image data). All the other parts of LDI snapshots that do not fit into the chosen SOP class attributes structure we store under DICOM private tags defined by Aïmago for this purpose. This at least allows any DICOM conformant viewer software to view Aïmago LDI snapshot images. Of course, the images are not recognized as LDI and the information stored under the private tags remains uninterpretable for non-Aïmago DICOM viewers.

3.2 Long Term Solution: Add LDI Modality Support to DICOM

The only option for a real solution for storing LDI files in DICOM is to integrate LDI modality support to DICOM standard specifications. We consider this to be a long term solution because according to the previous experience reported in [5] the process of development and approval of a supplement to DICOM may take from 9 months up to 3.5 years of time starting from its kick-off at the standards committee. This process also requires some of the interested parties to take the lead in the development effort and to serve as editor of the supplement while it is being developed. In addition to the leading organization, there should be other interested organizations that participate in the effort. This means that additional time is needed to organize the effort and its participants before the process at the standards committee can be started.

This paper can be considered as the initial step in the process that may eventually finish by the desired support of LDI modality in DICOM standard.

Let us now present details about the attributes that according to our experience need to be present in DICOM IOD specifications to allow for storage of LDI modality files. Table 1 presents the attributes that are necessary for storing LDI files and that have already analogs defined in DICOM. Table 2 presents the attributes that are necessary for storing LDI files and that do not have similar elements defined in DICOM. "M/O" fields in the tables indicate if an attribute is mandatory or optional.

Table 1. LDI files attributes that have analogs defined in DICOM

Attribute	Element tag	M/O	Description (from DICOM)
Patient Module			
Patient's Name	(0010,0010)	M	Patient's full name
Other Patient Names	(0010,1001)	O	Other names used to identify the patient.
Patient ID	(0010,0020)	M	Primary hospital identification number or code for the patient
Patient's Birth Date	(0010,0030)	M	Birth date of the patient
Patient's Sex	(0010,0040)	M	Sex of the patient (M/F/O)
Patient's Comments	(0010,4000)	O	User-defined additional information about the patient
General Study Module			
Study Instance UID	(0020,000D)	M	Unique identifier for the Study.
Study Date	(0008,0020)	M	Date the Study started.
Study Time	(0008,0030)	M	Time the Study started.

Table 1. (*Continued*)

Referring Physician's Name	(0008,0090)	M	Name of the patient's referring physician
Accession Number	(0008,0050)	M	A RIS generated number that identifies the order for the Study
Study Description	(0008,1030)	O	Description of the Study
General Equipment Module			
Manufacturer	(0008,0070)	O	Manufacturer of the equipment that produced the series.
Manufacturer's Model Name	(0008,1090)	O	Manufacturer's model name of the equipment that produced the series.
Device Serial Number	(0018,1000)	O	Manufacturer's serial number of the equipment that produced the series.
Software Version(s)	(0018,1020)	O	Manufacturer's designation of software version of the equipment that produced the series.
Institution Name	(0008,0080)	O	Institution where the equipment that produced the series is located.
Institutional Department Name	(0008,1040)	O	Department in the institution where the equipment is located
General Series Mod.			
Modality	(0008,0060)	M	Modality type (OT – for now, LDI – for future)
Series Instance UID	(0020,000E)	M	Unique identifier of the Series
Series Date	(0008,0021)	O	Date the Series Started
Series Time	(0008,0031)	O	Time the Series Started
General Image Mod.			
Instance Number	(0020,0013)	M	A number that identifies this image
Patient Orientation	(0020,0020)	O	Patient orientation relative to the image plane
Content Date	(0008,0023)	M	The date the image pixel data creation started
Content Time	(0008,0033)	M	The time the image pixel data creation started
Acquisition Date	(0008,0022)	M	The date the acquisition of data that resulted in the image started
Acquisition Time	(0008,0032)	M	The time the acquisition of data that resulted in the image started
Image Pixel Module			
Samples per Pixel	(0028,0002)	M	Number of samples (planes) in this image.
Photometric Interpretation	(0028,0004)	M	Specifies the intended interpretation of the pixel data
Bits Allocated	(0028,0100)	M	Number of bits allocated for each pixel sample.
Bits Stored	(0028,0101)	M	Number of bits stored for each pixel
High Bit	(0028,0102)	M	Most significant bit for pixel sample data.
Pixel Representation	(0028,0103)	M	Data representation of the pixel samples.
Planar Configuration	(0028,0006)	M	Indicates whether the pixel data are sent color-by-plane or color-by-pixel
Rows	(0028,0010)	M	Number of rows in the image
Columns	(0028,0011)	M	Number of columns in the image
Pixel Data	(7FE0,0010)	M	A data stream of the pixel samples that comprise the image.

Table 1. (*Continued*)

Multi-frame Module			
Number of Frames	(0028,0008)	M	Number of frames in a multi-frame image
Frame Increment Pointer	(0028,0009)	M	Contains the data element tag of the attribute that is used as the frame increment in multi-frame pixel data.
Frame Time Vector	(0018,2001)	M	An array which contains the real time increments (in milliseconds) between frames for a multi-frame image.
SOP Common Mod.			
SOP Class UID	(0008,0016)	M	Uniquely identifies the SOP class
SOP Instance UID	(0008,0018)	M	Uniquely identifies the SOP instance

Table 2. LDI files attributes that do not have analogs defined in DICOM

Attribute	**M/O**	**Description**
LDI Primary Group		A primary LDI image (or a sequence of images) rendered by the LDI camera to the end-user.
LDI Frame Time Vector	O	Timebase data for a sequence of images
LDI Primary Width	M	LDI Image Width (in pixels)
LDI Primary Height	M	LDI Image Height (in pixels)
LDI Primary BPP	M	LDI Image Pixel Resolution (in bytes)
LDI Primary Number of Frames	M	Number of LDI frames in this sequence
LDI Primary Data	M	LDI Data. Contains an image or sequence of images.
LDI Primary Colormap Length	O	LDI Image Colormap Length (in bytes)
LDI Primary Colormap BPP	O	LDI Image Colormap Pixel Resolution (in bytes)
LDI Primary Colormap Data	O	LDI Colormap Data. Contains an LDI colormap, mapping data to RGB values for rendering.
LDI Primary Thumbnail Width	O	LDI Image Thumbnail Width (in pixels)
LDI primary Thumbnail Height	O	LDI Image Thumbnail Height (in pixels)
LDI Primary Thumbnail BPP	O	LDI Image Thumbnail Pixel Resolution (in bytes)
LDI Primary Thumbnail Data	O	LDI Image Thumbnail Data. Contains an LDI thumbnail for a fast indexing of LDI images.
LDI Primary Orientation	O	LDI Image Orientation. Contains the orientation of the image relatively to the device.
LDI Primary Image Type	O	LDI Image Type (Perfusion, Concentration, Speed)
LDI Primary Compres. Type	O	LDI Image Compression Type
LDI Primary Compres. Ratio	O	LDI Image Compression Ratio
LDI RAW Group		A RAW LDI image (or a sequence of images) given by the LDI camera for post-processing.
LDI Frame Time Vector	O	Timebase data for a sequence of images
LDI RAW Width	O	LDI Image Width (in pixels)
LDI RAW Height	O	LDI Image Height (in pixels)
LDI RAW BPP	O	LDI Image Pixel Resolution (in bytes)
LDI RAW Number of Frames	O	Number of LDI Images in this sequence
LDI RAW Data	O	LDI Data. Contains an image or sequence of images.
LDI RAW Colormap Length	O	LDI Image Colormap Length (in bytes)
LDI RAW Colormap BPP	O	LDI Image Colormap Pixel Resolution (in bytes)

Table 2. (*Continued*)

LDI RAW Colormap Data	O	LDI Colormap Data. Contains a LDI colormap, mapping data to RGB values for rendering.
LDI RAW Thumbnail Width	O	LDI Image Thumbnail Width (in pixels)
LDI RAW Thumbnail Height	O	LDI Image Thumbnail Height (in pixels)
LDI RAW Thumbnail BPP	O	LDI Image Thumbnail Pixel Resolution (in bytes)
LDI RAW Thumbnail Data	O	LDI Image Thumbnail Data. Contains an LDI thumbnail for a fast indexing of LDI images.
LDI RAW Orientation	O	LDI Image Orientation. Contains the orientation of the image relatively to the device.
LDI RAW Image Type	O	LDI Image Type (Perfusion, Concentration, Speed)
LDI RAW Compression Type	O	LDI Image Compression Type
LDI RAW Compression Ratio	O	LDI Image Compression Ratio
Color Group		A Color image (or a sequence of color images) provided by the Color camera to complement LDI.
Color Frame Time Vector	O	Timebase data for a sequence of images
Color Image Width	O	Color Image Width (in pixels)
Color Image Height	O	Color Image Height (in pixels)
Color Image BPP	O	Color Image Pixel Resolution (in bytes)
Color Number of Frames	O	Number of Color Images in this sequence
Color Image Data	O	The data contain an image or a sequence of images.
Color Image Colormap Length	O	Color Image Colormap Length (in bytes)
Color Image Colormap BPP	O	Color Image Colormap Pixel Resolution (in bytes)
Color Image Colormap Data	O	Color Image Colormap Data. Contains an image or a sequence of images.
Color Image Thumbnail Width	O	Color Image Thumbnail Width (in pixels)
Color Image Thumbnail Height	O	Color Image Thumbnail Height (in pixels)
Color Image Thumbnail BPP	O	Color Image Thumbnail Pixel Resolution (in bytes)
Color Image Thumbnail Data	O	Color Image Thumbnail Data. Contains a Color Image thumbnail for faster indexing of color images.
Color Image Orientation	O	Color Image Orientation. Contains orientation of the image relatively to the device.
LDI X in Color	O	LDI Image X Offset in the Color Image (in pixels)
LDI Y in Color	O	LDI Image Y Offset in the Color Image (in pixels)
LDI Width in Color	O	LDI Image Width in the Color Image (in pixels)
LDI Height in Color	O	LDI Image Height in the Color Image (in pixels)
LDI Zoom Factor	O	Ratio between the LDI Image and the Color Image
Color Compression Type	O	Color Image Compression Type
Color Compression Ratio	O	Color Image Compression Ratio
Device Group		
Field of View Width	M	Field of View Width of the LDI Camera (in cm)
Field of View Height	M	Field of View Height of the LDI Camera (in cm)
Focus Distance	M	Focal distance of the LDI Camera (in cm)
Primary IR Wavelength	M	Primary LDI illumination wavelength (in nm)
Secondary IR Wavelength	O	Secondary LDI illumination wavelength (in nm)
Number of active IR lasers	O	Number of active infra-red illumination lasers
Diameter of the IR beam	O	Diameter of active infra-red illumination laser beams
Power of IR beam per surface unit	M	Mean power of the active infra-red illumination laser per surface unit
Acquisition Frame rate	O	Frame rate of images acquired from the LDI Camera

4 Conclusion

In this article we reviewed the problem of absence of LDI modality support in DICOM. This is an important problem, since Laser Doppler Imaging technique is around 20 years old and at present time LDI medical devices are spread in hospitals around the world. Due to the absence of LDI support in DICOM such devices cannot be fully integrated into standard hospitals' workflows and their produced images cannot be viewed by standard DICOM-viewer software.

We have presented a set of requirements that can be useful for representation of LDI modality in DICOM standard specifications. The requirements are based on our practical experience of manufacturing LDI medical equipment at Aïmago SA.

The list of requirements presented in this paper should not be considered as a final proposal for DICOM standard. It is rather the first step in the requirements definition. This step may be followed by a discussion of all parties interested in integration of LDI support into DICOM standard. The goal of such discussions would be to achieve a worldwide consensus on the requirements and to present the requirements to the attention of DICOM standardization committee.

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Generating SNOMED CT Subsets from Clinical Glossaries: An Exploration Using Clinical Guidelines

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Abstract. The large SNOMED CT (SCT) terminology has gained adoption in the last years. However, its practical application for coding clinical information is hampered by its complexity and size. The mechanism of subsets allows for creating clusters of SNOMED CT terms that cover a particular application or clinical domain. These subsets are usually defined following some sort of consensual expert-driven process that is effort-intensive. The automated generation of subsets from clinical document corpora have been proposed elsewhere, but they still require a collection of documents that is representative for the targeted domain. This paper describes an experiment in using clinical guidelines' glossaries as a seed terminology for automatically generating subsets by traversing SNOMED relationships. Quantitative analysis reveals that traversing patterns need to be limited, and expert assessments point out that the approach may be viable at least for bootstrapping the process of elaborating the subsets.

Keywords: SNOMED CT, subsets, clinical guidelines, glossaries.

1 Introduction

In the last few years there has been a growing body of literature about the use of SNOMED CT [1] (Systematized Nomenclature of Medicine Clinical Terms) as an standard reference terminology aimed at achieving interoperability between clinical systems that can be implemented and used in different clinical settings. The sheer size of SNOMED CT is a significant issue in developing, using and maintaining it. So, extracting meaningful fragments from this terminology, is a key issue for using it. Yet, there are few detailed encoding instructions showing how this can be done and the issues involved.

Several techniques for extracting fragments of ontologies have been developed [2, 3]. Most of these techniques rely on employing various heuristics for determining which classes (concepts) are relevant and which are not. The algorithm implemented in the PROMPT-FACTOR tool [4] is one example; given a domain vocabulary and ontology, it retrieves an initial subset, and then, the vocabulary is expanded with the other atomic concepts or roles of the subset. Another example is the algorithm [5] which was used for segmentation of the medical ontology GALEN [6]. In [7] a user is

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allowed to state what relations are to be considered in the procedure of making the subset. For refining the results to their own requirements the method allows the user to run the method with different configurations.

However this paper describes a heuristic method used for developing SNOMED CT subsets derived from clinical terms collected from clinical guidelines'(CG) glossaries. As illustration, we have used two specific-domain examples: first, the extraction of subsets including information relevant to the recognition and initial management of ovarian cancer, and then, subsets in the context of Parkinson's disease diagnosis and management in primary and secondary care.

The rest of this paper is structured as follows: in Section 2, background on the material to be used in this paper (clinical guidelines and SNOMED CT) is provided. The methods supporting our encoding process is given in Section 3; details about the steps involved in these methods are provided in Sections 3.1-3.4. In the fourth section quantitative results obtained by the encode method are described. We conclude with some remarks about future work.

2 Background

Clinical guidelines are recommendations based on the best available evidence on the appropriate treatment and care of people with specific diseases and conditions. They provide guidance and set quality standards for improving people's health and prevent and treat ill health.

Guidelines can provide recommendations for the treatment and care of people by health professionals, and also can be used to develop standards to assess the clinical practice of individual health professionals [8].

Clinical guidelines review a number of clinical questions which focus on areas of uncertainty or where there is a wide variation in clinical practice. These clinical questions were chosen using a consultative process involving patient groups, representatives from relevant professional organizations and the pharmaceutical industry. Therefore, the health professionals' knowledge included in clinical guidelines, is very representative about the particular domain covered, both in content and vocabulary used to express it. Clinical guidelines usually include glossaries which provide a list of specific clinical and medical terms which have been referred to in them.

SNOMED CT is a comprehensive, multilingual clinical reference terminology that allows healthcare providers to record clinical encounters accurately and unambiguously. It can be used to code, retrieve, and analyze clinical data. In January 2011 it contained over 390,000 concepts, 1,160,000 English descriptions and 1.40 million relationships. It consists of three core building blocks:

- **Concepts:** each *concept* represents a single clinical meaning
- **Descriptions:** each concept *description* is a term (a phrase used to name a concept) or name assigned to a SNOMED CT concept; any concept may have any number of descriptions
- **Relationships:** each *relationship* represents a logical relationship between two concepts

Numeric codes (ConceptID, DescriptionID and RelationshipID) identify every instance of the three core building blocks. Unlike previous coding schemes, SNOMED CT is not a code-dependant hierarchy; instead, it relies on a large number of explicitly defined relationships. Moreover, multiple SNOMED CT concepts can be joined together to create post-coordinated expressions that allow users to record complex clinical conditions.

SNOMED CT is both a coding scheme, identifying concepts and terms, and a multidimensional classification. The content coverage of SNOMED CT is organized into 19 hierarchies including: clinical finding, procedure, observable entity, body structure, organism, substance, pharmaceutical/biological product, specimen, special concept, physical object, physical force, event, environment or geographical locations, social context, situation with explicit context, staging and scales, linkage concept, qualifier value and record artifact.

3 Methods

In this paper we have used the NICE (National Institute for Health and Clinical Excellence) clinical guideline CG122 (Full Guideline – April 2011)[1] which reviews a number of clinical questions that involve the detection, diagnosis and initial management of ovarian cancer, and, clinical guideline CG35 (Full Guideline – July 2011)[2] for Parkinson's disease diagnosis and management in primary and secondary care. Also, for this research, the January 31, 2011 International Release version of SNOMED CT was used.

The encoding process involves the following steps:

- SCT data preparation.
- Extract the clinical guidelines' glossary- this is the *input data set*.
- Encode the data items included in the input data set - this is an initial SNOMED subset named *encoded data set (EDS).*
- Apply "heuristic rules" to expand an input SNOMED subset with other SCT concepts and export the concept codes – in this step is generated a new *SNOMED CT subset*. This step can be iterated.

An overview of this method is shown in Figure 1.

3.1 SCT Data Preparation

SCT is distributed as text files. Hence this distribution data needs to be restored to a framework to identify SCT's elementary data structures. To manipulate the data through the computational framework is necessary a fast and consistent way. Therefore, the raw data, consisting of the three tables; concepts, descriptions and relationships, were placed into the relational database management system, MySQL.

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[1] http://guidance.nice.org.uk/CG122

[2] http://guidance.nice.org.uk/CG35

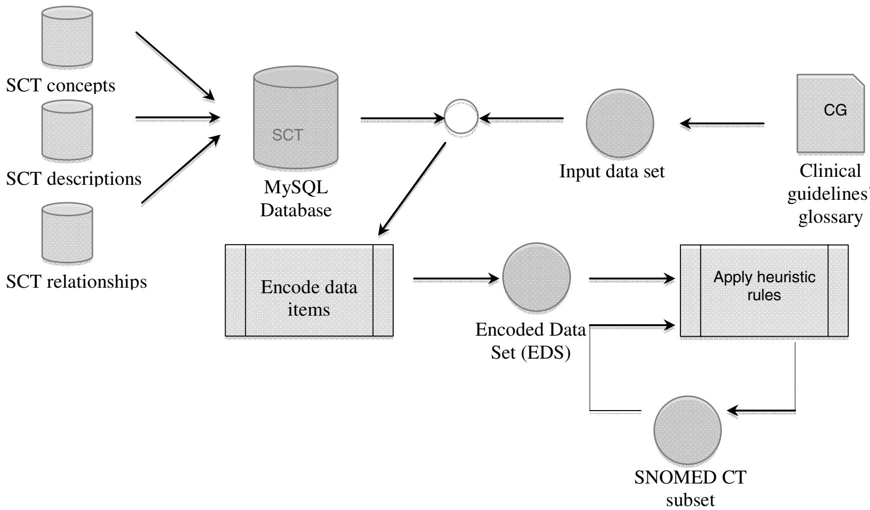

Fig. 1. An overview of the method for automatically generating SNOMED subsets from clinical glossaries

3.2 Extract the Clinical Guideline's Glossary

The input data set extracted from the clinical guidelines' glossary for detection, diagnosis and initial management of ovarian cancer (hereinafter denoted as "Input_CG122") contained 126 items; as cites, chemotherapy and gastro-splenic ligament are three data items examples contained in Input_CG122.The data set extracted from clinical guidelines'glossary for Parkinson's disease diagnosis (hereinafter denoted as "Input_CG35") contained 98 elements; in this case, sialorrhoea and dyskinesia are two glossary items examples.

3.3 Encode the Data Items Included in the Input Data Set

Lexical string matching is our method of locating the SNOMED CT concepts to identify all the SCT candidates. The matching algorithm takes each data item from the input data set and attempts to find each SCT Description in the description table of the MySQL database which matches.

Using the SNOMED CT fields *DescriptionStatus* and *ConceptStatus*, it checks that both the description and the concept are in active use.The algorithm returns results by exact match. Exact matches occur when all words are found in the SNOMED CT description and are in the same order as the data item. The SNOMED CT description must not contain additional words. The *encoded data set*(to be hereinafter denoted as "EDS")contains all the SCT concepts associated with each description matching with a data item; it is the initial SCT subset.

3.4 Apply "Heuristic Rules" to Expand an Input SNOMED CT Subset

This phase of the method is intended to extract relevant parts of SNOMED CT which are likely to be related to the clinic domain under consideration. In this sense, we have chose some "heuristic rules" which establish certain patterns to be applied for traversing SNOMED relationships; therefore an input SCT subset is expanded meaningfully according to experimental criteria.

SNOMED CT provides a rich set of inter-relationships between concepts, which are at the heart of it. Each relationship is defined as an object-attribute-value triple. The object, identified by a concept identifier (ConceptId1), is the source concept, the one that has the relationship. The attributes establish the type of the relationship (RelationshipType), and is also a SNOMED CT concept. The value is the target (ConceptId2).There are four categories of relationships: defining, qualifying, historical and additional. There are two types of defining relationships:

- *Super - Subtype relationships*, also known as *IS_A relationships* or *Parent-Child relationships*

These relationships define specific concepts as children of more general concepts (parents) providing the main semantic hierarchy that relates concepts to one another. The Super - Subtype relationship concept has 116680003 as conceptID and FSN(FullySpecifiedName) |is a|. A given concept (Concept_X) may have subtype children (concepts with a subtype relationship referring to Concept_X) or supertype parent (concepts referred to by a subtype relationship from Concept_X).

- *Attribute relationships*

These relationships contribute to establish defining characteristics about a concept (ConceptId1); the RelationshipType indicates the nature of the defining attribute, and ConceptId2 represents the value of that attribute.

Therefore, SNOMED CT Concept Model is a multiaxial, hierarchical classification system; its graph structure , with concepts and relationships represented as nodes and arcs, has a main axis, which contributes the hierarchical type based aspect of a concept definition, and another concepts associated with concept's characteristics.

The heuristic rules chosen in our study, were induced by SNOMED CT axes mentioned above, and bearing in mind that, when they are applied, cause an expansion of *the input SCT subset* just along one dimension, using heritage criteria, or, through two dimensions, applying the latter together with concept's defining characteristics.

Next, the defined heuristic rules, denoted as "*HIp*" and "*HAj*" are provided; the application of each heuristic rule gives rise to a SNOMED CT subset denoted as "*SCT_HIp*" or "*SCT_HAj*".

- *HIp*(p=1, 2, 3) : For each concept (node) contained in EDS, generate all level jconcepts (vertices), $p \geq j \geq 1$, through relationship 116680003|is a|;the application of this rule allow us to obtain SNOMED subsets with increasing granularities, ie, concepts representing increasingly specific levels of detail are added to it; in this way, a new SNOMED subset denoted by SCT_HIp is obtained.

- *HAj* (j=1, 2, 3) : For each concept Concept_X contained in *SCT_HIp* , with j = p, generate all concepts (attributes' values), using relationships with RelationshipType ≠116680003, referring to Concept_X ; SCT_HIp is expanded and SCT_HAj is obtained.

When rules are applied, duplicate concepts are eliminated from the output SCT subset.

For instance

The word *Chemotherapy* is an element included in Input_CG122, the set which contains the items extracted from the clinical guidelines' glossary for detection, diagnosis and initial management of ovarian cancer. This input data item matches with the SNOMED CT concept 367336001|chemotherapy|; it belongs to the semantic category Procedure, one of the 19 Top-level hierarchies, through which SNOMED CT content is organized. Therefore, concept 367336001|chemotherapy| is an EDS member.

Then, if the heuristic rule named HI2 is chosen to be applied, the encoded data set (EDS), which is the input SNOMED subset, is expanded; all level j, $2 \geq j \geq 1$, concepts are added to EDS. In Figure 2 is shown some descendants of concept 367336001|chemotherapy|, ie concepts which are elements of SCT_HI2 :

- 266719004|oral chemotherapy|, 265762008|subcutaneous chemotherapy| and 265760000|intravenous chemotherapy| are level 1 descendants (children)
- 51534007|oral chemotherapy for malignant neoplasm| is a level2 descendant

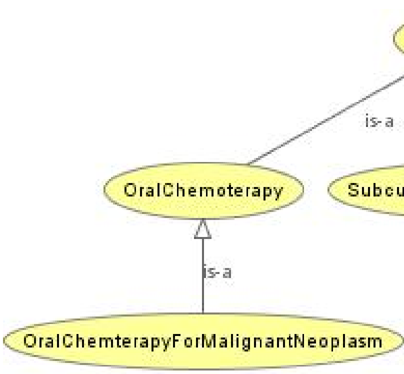

Fig. 2. Some descendants of concept 367336001|chemotherapy| (each concept node belongs to SCT_HI2)

Once the Snomed subset SCT_HI2 has been obtained, let us proceed to apply HA2 heuristic rule, considering SCT_HI2 as the input subset ; thus, SNOMED subset named SCT_HA2 is generated.

Fig. 3 shows the new graph (fragment) obtained:

- 51534007|oral chemotherapy for malignant neoplasm (procedure)|: 363703001|has intent (attribute)| = 262202000|therapeutic intent (qualifier value)|

The *attribute* (has intent) specifies the intent of the *procedure* (oral chemotherapy for malignant neoplasm) and the *value* (therapeutic intent) indicates the nature of the procedure.

- 51534007|oral chemotherapy for malignant neoplasm|:
  363701004|direct substance (attribute)| = 410942007|drug or medicament (substance)|

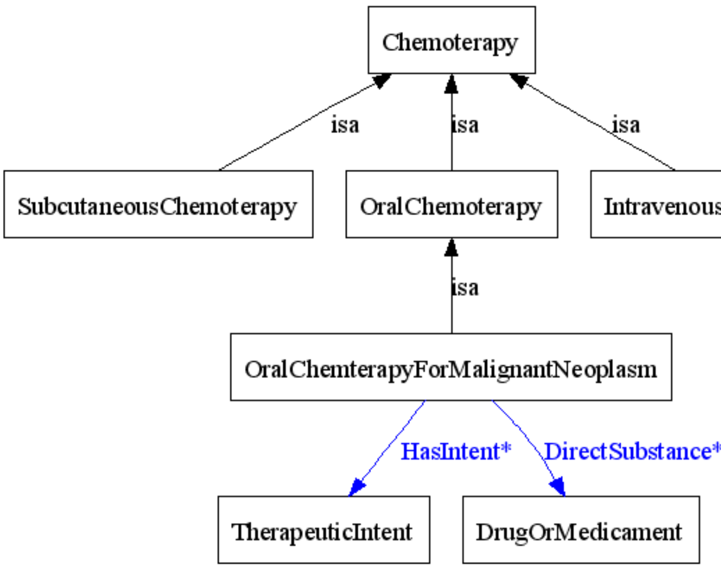

Fig. 3. Graph (fragment) whose vertices represent concepts included in SCT_HA2

4 Results and Discussion

The following section describes quantitative results obtained by the encoding method described above, both in the case of clinical guideline CG122 (ovarian cancer) as in the case of CG35 (Parkinson's disease).

The input set Input_CG122 (glossary items) contained 126 elements and Input_CG35 contained 98 items; in each case, Table 1 indicates that 71 (≈ 53%) and 20 (≈ 20%) glossary data items were matched with SNOMED CT concepts, respectively.Examples of unencoded glossary terms are available in Table 2.Therefore, the number of SNOMED CT concepts contained in the encoded data set, EDS, is 71 and 20 for each of the case studies.

Table 1. A summary of the input data set (glossary items) and matching terms

	CG122	**CG35**
No. of clinical terms collected from clinical guidelines' glossary	126	98
No. of exact matches	71	20

Table 2. Sample glossary items that could not be encoded with SNOMED CT

Glossary item(CG122)	Glossary item(CG35)
Cytology	Lee Silverman Voice Treatment (LSVT)
Gastro-splenic ligament	Motor fluctuations
Percutaneous core biopsy	Cochrane Review

Based on the initial SNOMED CT subset EDS, traversing Is_a (HIp heuristic rules) relationships recursively, three new subsets were generated: SCT_HI1, SCT_HI2 and SCT_HI3. They are interrelated by the set inclusion relation between sets; their cardinalities are shown in Table 3.

The SNOMED CT subset covering 53% (20%) of codable glossary items, plus an expansion of descendants with increasing order of granularity intended to extract relevant parts of SNOMED, contains 1,203 (100), 7,199 (142) and 15,117 (153) SNOMED concepts. The SCT release (January 2011) has 293,670 active concepts; therefore, these expansions' cardinalities correspond to 0,4 % (0,03%), 2,4% (0,03%) and 5,14% (0,05%) of the content, respectively. Therefore, the coverage of these subsets uses a maximum of 5,14 (0,05) percent of SCT.

Table 3. Encoding summary statistics (EDS : Encoded data set)

Input SNOMED CT subset	No. of concepts in input subset		Heuristic rule applied	Output SNOMED CT subset	No. of concepts in output subset	
	CG122	CG35			CG122	CG35
EDS	71	20	HI1	SCT_HI1	1,203	100
EDS	71	20	HI2	SCT_HI2	7,199	142
EDS	71	20	HI3	SCT_HI3	15,117	153
SCT_HI1	1,203	100	HA1	SCT_HA1	1,622	141
SCT_HI2	7,199	142	HA2	SCT_HA2	8,607	184
SCT_HI3	15,117	153	HA3	SCT_HA3	17,628	197

The *set difference* of sets A and B, and, the *intersection* of A and B, written A \ B and A ∩ B respectively, where A and B are SNOMED CT subsets, were computed for quantitatively assessing the degree of the semantic expansion [9] between two subsets, which were obtained using the method detailed above. The results are shown in Table 4. Some obvious results, or results easily inferred from table 3, have been omitted.

Hereinafter, we denote the cardinality of the set A as #(A). The following quantitative analysis take in account data appearing in the second column of Table 4.

The SNOMED CT subset SCT_HA3, which is the one with maximum cardinality, comprises 17, 628 SNOMED concepts (table 3), and uses 6 percent of SCT. This subset was generated expanding SCT_HI3 subset by the addition of 2511 new concepts to it, representing attributes' values, among them,1408 were attributes' values referring to concepts included in SCT_HI2.Also, SCT_HI3 increased on 7918 concepts with respect to SCT_HI2. Hence, the degree of the semantic expansion measured in terms of concepts, between SCT_HA3 and SCT_HI2, is 10,429 concepts.

Table 4. Set difference and Intersection of SNOMED CT subsets

Subsets Operations	**No. of concepts/CG122**	**No. of concepts/CG35**
SCT_HI1 \ EDS	1,132	80
SCT_HI2 \ EDS	7,128	122
SCT_HI3 \ EDS	15,046	133
SCT_HA1 \ SCT_HI1	419	41
SCT_HA1 \ SCT_HI2	389	41
SCT_HA1 \ SCT_HI3	358	41
SCT_HI2 \ SCT_HA1	5966	42
SCT_HA2 \ SCT_HI1	7,406	84
SCT_HA2 \ SCT_HI2	1,408	42
SCT_HA2 \ SCT_HI3	1,291	42
SCT_HA3 \ SCT_HI1	16,427	97
SCT_HA3 \ SCT_HI2	10,429	55
SCT_HA3 \ SCT_HI3	2,511	44
SCT_HI1 ∩ SCT_HA1	1,203	100
SCT_HI1 ∩ SCT_HA2	1,201	100
SCT_HI1 ∩ SCT_HA3	1,201	100
SCT_HI2 ∩ SCT_HA1	1,233	100
SCT_HI2 ∩ SCT_HA2	7,199	142
SCT_HI2 ∩ SCT_HA3	7,199	142
SCT_HI3 ∩ SCT_HA1	1,264	100
SCT_HI3 ∩ SCT_HA2	7,316	142
SCT_HI3 ∩ SCT_HA3	15,117	153

Taken in account that in SNOMED CT some classes are defined in extension (i.e. via a list of their subclasses) rather than in intension (i.e. via a list of characteristics) [10], we considered appropriated to express the semantic expansion by two kinds of "semantic components" [11] : 1. Hierarchical-component : 7918 concepts (i.e. component weight ≈0,76) and 2. Roles-component: 2511 concepts (i.e. component weight ≈ 0,24). In a similar way, we can state the semantic expansion between SCT_HA3 and SCT_HA2 : 1. Hierarchical-component : 7918 concepts (i.e. component weight ≈ 0,87) and 2. Roles-component: 1103 concepts (i.e. component weight ≈ 0,13).

The relative growth rates associated with each expansion are decreasing :(one dimension) SCT_HI1&SCT_HI2 ≈ 4,98 and SCT_HI2&SCT_HI3≈ 1,09; (two dimensions) SCT_HI1&SCT_HA1≈ 0,34, SCT_HI2&SCT_HA2 ≈ 0,19 and SCT_HI3&SCT_HA3 ≈ 0,16. In contrast, the absolute changes are increasing : SCT_HI1&SCT_HI2 = 5996 concepts and SCT_HI2&SCT_HI3 = 7918 concepts ; SCT_HI1&SCT_HA1 =419 concepts, SCT_HI2&SCT_HA2 =1,408 concepts and SCT_HI3&SCT_HA3 = 2,511 concepts. These results mean that although increments produced in each expansion are elements of an increasing sequence, these growths represent a decreasing proportion respect to the cardinality of the corresponding input subset.

Now, we consider data which appear in the third column of Table 4.

For the second case (clinical guideline CG35), the SNOMED CT subset SCT_HA3, which is the one with maximum cardinality, comprises 197 SNOMED concepts (table 3), and uses 0,06 percent of SCT.

From #(SCT_HI3 ∩ SCT_HA2) = 142 and #(SCT_HA2 \ SCT_HI3) = 42, together with

#(SCT_HA2) = 184 (Table 3), we can infer that all target concepts (attribute's value) belonging to SCT_HA2 has level less than or equal to two in a different hierarchy than that of the source concept. The same happens with SCT_HA1. Instead, for the other case, using data appearing in the second column of Table 4, #(SCT_HI3 ∩ SCT_HA2) = 7,316 and#(SCT_HA2 \ SCT_HI3) = 1,291, together with

#(SCT_HA2) = 8,607 (Table 3), imply that 117 target concepts belonging to SCT_HA2 has level three in a different hierarchy than that of the source concept .

5 Conclusions

This paper has explored the use of clinical guidelines' glossaries as a seed terminology for automatically generating subsets covering a clinical domain by traversing SNOMED relationships. Quantitative analysis reveals two main facts: (1) the application of heuristic rules needs to be limited and (2) as the rules operate in different "dimensions" the choice of the kind of rule to be applied has to be carefully balanced.

Although our primary concern in this pilot was to make quantitative analysis related to the intrinsic characteristics of the method, expecting to obtain a brief assess about the benefits of it linked to semantic boundary delimitation , two clinicians reviewed a small number of concepts included in each of the generated subsets, evaluating their relevance to the chosen domain. In this sense, the conclusions were not definitive, but they point out that the approach may be viable as starting point in the process of elaborating subsets.

The data shown in the third column of Table 4 shows that the order of magnitude is smaller compared with data appearing in second column. This suggests that the nature of the disease being considered in the chosen clinical guideline has important implications when generating SNOMED subsets.

Future work will deal with an extensive evaluation of different approaches for generating subsets under experimental settings.

Also, an important point of care to be considered, is the use of natural language processing techniques, which may allow this method to be refined in the encoding phase by generating a more accurate encoded data set from the items in the glossaries.

Although still in a preliminary stage the work has established that it is feasible to construct useful initial subsets for SCT using clinical guidelines' glossaries, enabling the development of a methodology for deriving SNOMED subsets.

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Molecular Visualization with Supports of Interaction, Immersion and Collaboration among Geographically-Separated Research Groups

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Abstract. This paper explores the possibilities of integrate two or more geographically-separated research groups in the same molecular visualization. It is presented the JViewer (JAMP Molecular Viewer), which is a molecular visualization application with interaction, immersion and collaboration. The interaction and immersion are provide by the use of Virtual Reality technology; and the communication and synchronization using JAMP platform (Java Architecture for Media Processing), which is a distributed programming environment for multimedia applications.

Keywords: Molecular visualization, collaboration, immersion, interaction, Virtual Reality, JAMP Platform.

1 Introduction

Technological advances become feasible to use computer as laboratories, in which students immerse themselves within interactive contexts that challenge and extend their understanding. In 1965 was developed by Cyrus Levinthal the first interactive molecular visualization system (IMVS) [1]. Throw a plastic "globe" (the predecessor to the torque ball) the system was manipulated. This device enabled the user to orient a line drawing of a three-dimensional molecular model. By placing a light pen over the computer display, it was possible to select menu options, choose an object or execute zoom into parts of a molecule.

Nowadays the researchers are using Virtual Reality technologies to improve the molecular viewers. Virtual Reality offers solutions to build computer generated environments which combines immersion, interaction, multi sensing and a three-dimensional world. A molecular viewer based on Virtual Reality allows investigate the structure, properties and dynamics of a molecular system which are extremely complex and comprises millions or billions of atoms in an immersive and interactive environment. The user can interact with the molecules in real time (rotate, resize, measure, verify distances between atoms, angles, adjust rendering parameters) and he

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can be immersed in the environment using stereoscopic vision. There is plenty of molecular viewers available (VRDD [2], Distributed PaulingWorld [3], Jmol adapted for collaborative use [4], Interactive Molecular Visualization System [5], AMMP-Vis [6], KinImmerse [7], MICE [8], VrMol [9], Gesture-Based Molecular Visualization Tool [10]). Some of them were projected to support local collaborative work. However, the author's don´t know none of them that support collaborative work where the users are geographically-separated. Collaborative work means interdependence of activities. The users are interdependent in their work in the sense that one user's actions will change the state of a set of objects and processes and, in turn, this change of state has implications, directly or indirectly, for the work of the other members of the ensemble, and vice versa [11].

This paper describes the application JViewer which is an immersive, interactive and collaborative environment for visualization of molecules, where two or more geographically-separated research group can work together at the same time. The user can get immersion using stereo view. The interaction is reach throw the use of devices as Wii Remote and mouse. The collaboration was obtained throw the integration of geographically-separated research groups working in the same molecule simulation.

This paper is organized as follows: the section 2 present the JAMP Platform [12-16], which is the software infrastructure used to develop the JViewer (JAMP Molecular Viewer); in the section 3 is presented the JViewer, which is the molecular viewer based on JAMP (Java Architecture for Media Processing) Platform and Virtual Reality technologies; conclusion and references are, respectively, in sections 4 and 5.

2 JAMP Platform

The Fig. 1 presents the JAMP (Java Architecture for Media Processing), which is a set of frameworks and services that facilitates the development of distributed multimedia applications. JAMP applications can use any one of the available frameworks and service. Each framework provides a service: the JBroker framework is the base to develop new JAMP applications and provide the service of localization of other services; the AUDIO/VIDEO frameworks allow to add audio/video support in the applications and they offer the service of audio/video streaming; and the COLLABORATE framework is the foundation to collaborative application and it provides groupware services, as the concurrency control.

Although extensibility and code reuse are complex for distributed multimedia applications, it is important to achieve a way to make it easier. JAMP Platform aims to find a solution. It is part of its conceptions requirements as software extensibility and code reuse, providing a way to avoid software rebuild.

JAMP Platform uses RMI framework as a basic layer in its architecture, responsible for remote method invocations and object serialization in a local area network. Moreover, the platform has extra functionalities for distribution and it is available through the Broker Framework (JBroker). The JBroker is a program that contains a database of available servers at a moment. It enables clients to find distributed servers (remote objects) through the network. The use of server services occurs by remote method invocation (RMI) and after the successful search by its remote reference in the JBroker.

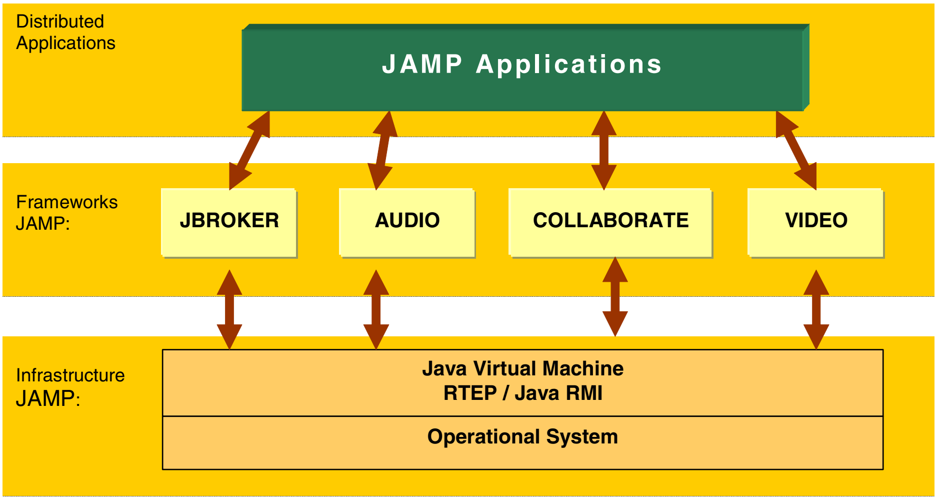

Fig. 1. JAMP Platform architecture

Middleware frameworks are basically used for integrating distributed components and applications. For instance, RMI (Remote Method Invocation) is capable of integrating distributed Java objects. It allows that an object invoke methods located in remote objects, which can take place in a computer with a completely different Java Virtual Machine, running on heterogeneous hardware architecture. It is also possible to send and receive objects through the network easily [17].

However, RMI performance over the internet is not good for a collaborative and immersive molecule visualization environment. When the application is distributed geographically, as the JViewer, the problem relies on transmission latency. So, it was developed a new communication protocol to supply the JViewer performance requirement. It was created the RTEP (Real Time Events Protocol) [18]. It is a protocol implemented at the application layer; it uses RTP (Real-time Transport Protocol)/RTCP (RTP Control Protocol) and has mechanisms to minimize the latency time issues, especially by managing the event queues and quality of connection of each server. These allow an efficient event distribution to the servers.

3 JViewer (JAMP Molecular Viewer)

The base of JViewer were the JBroker and the Collaborative frameworks with their respective services form the JAMP Platform, and the free Jmol [19] viewer. Fig. 2 shows the JViewer interface which displays molecular structures from files written in different formats: MOL,V3000, SDF, CTFile, CIF, mmCIF, CML, PDB, XYZ, XYZ+vib, XYZ-FAH, MOL2, Alchemy, CSF, GAMESS, Gaussian, Cube, Ghemical, MM1GP, HIN, Jaguar, MOLPRO, MOPAC, MGF, NWCHEM, odydata, xodydata, QOUT, SHELX, SMOL, spinput, GRO, PQR, Amber, JME, CASTEP, FHI-aims, VASP, DGrid, ADF, XSD, AGL, DFT, AMPAC, WebMO, Molden and PSI3. The formats are automatically recognized. The JViewer is extensible, so support to new formats can be added easily in the core.

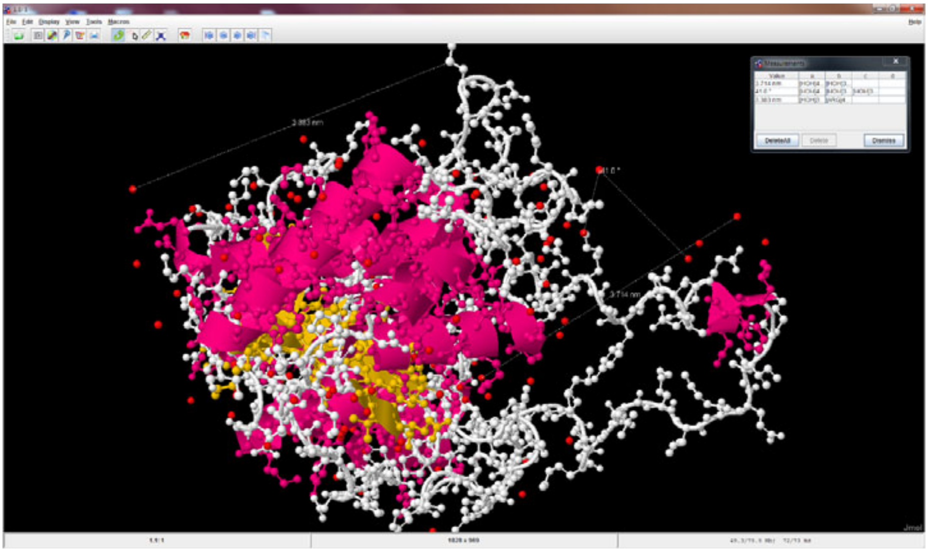

Fig. 2. System screen showing a protein molecule. Menu options allow changing the visualization properties.

As well as JAMP Platform the JViewer was written in Java, then inherited the multiplatform flexibility (it runs on Windows, Linux and MAC OS). Java provides a high-performance 3D rendering without specific hardware. The JViewer displays animations, vibration, orbitals and surfaces ; measure distances, angles and torsion angles; supports RasMol/Chime language scripts; and exports structures to various file formats (jpg, png, gif, ppm, pdf, POV-Ray, Gaussian, Maya, vrml, x3d e idtf).

The JViewer can be used in different ways by a teacher during a class. He can execute instruction on the fly or he can start the class from a specific simulation state. The system can read instructions that were done before. Some of the instructions are: rotation, translation, rendering type, colors, select molecule portions, animations, etc. Model position can be set and retrieved using these instructions. It is also possible make stereographic rendering for stereo displays and anaglyphic rendering.

JViewer recognizes all chemical elements of the periodic table. Each element receives a single color and its own radius. The atoms are rendered as cylinders and their colors can be chosen by the user. They can be identified with labels. The ability to simplify the molecule structure instead of showing all atoms and bonds is for great importance for the biological macromolecules study. JViewer possibilities to obtain this simplification viewing backbone, trace, ribbons, strands and cartoons. It accepts van der Waals radii percentages, as well as absolute values. Ionic radii are also supported, as an alternative to atomic.

Fig. 3 presents the JViewer hardware architecture. Each research group has a local server that controls the communication and synchronization of them. The local hardware infrastructure is flexible, it can be just a single personal computer or it can be a multiprojection system. When an event is generated by a client, it is send to the local server. When a local server receive an event, it replicate de event to the local and to its server, which propagates it to the others local servers.

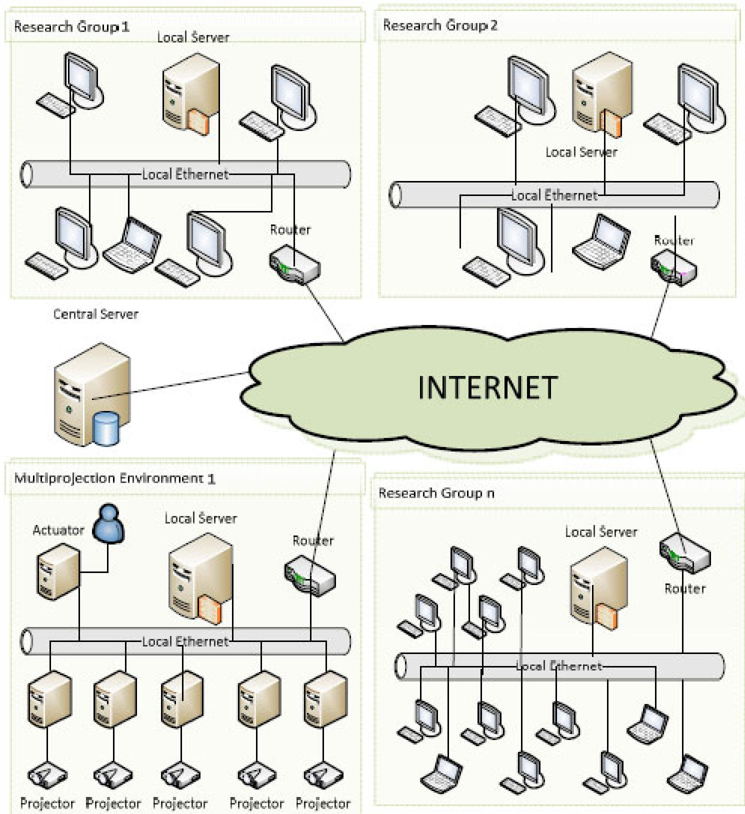

Fig. 3. JViewer hardware architecture

It was necessary to employ the framework JBroker and the Collaborative with their respective services in the JViewer development. After JViewer be started, it communicates with the JBroker to localize the Collaborative Service. After that, it communicates directly with the Collaborative Service which is implemented in the central server (Fig. 4). The Collaborative Service implements a centralized concurrency control, to manage all interaction with JViewer objects. JViewer implements WYSIWIS ("What You See Is What I See") paradigm where share the same visual perception of the work area. The disadvantages of the centralized concurrency control is that the central server is vulnerable to the failure (either computer or network), and it could become a network and processor bottleneck as all locks must pass through it. Local server at each site are responsible only for passing requests to the central server, and to sending any output sent to their clients from the central server. The advantage of a centralized scheme is that synchronization is easy, as state information is consistent since it is all located in one place. Events will never be received out of order (they are usually handled first-come, first-served).

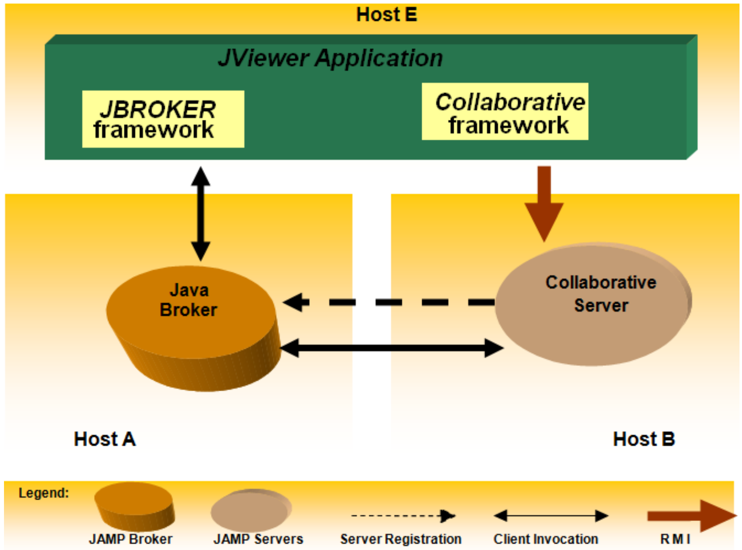

Fig. 4. JViewer software architecture

Collaborative work in JViewer resulted at least two benefits to the dispersed research groups:

1. A time-efficient method, where research team members must otherwise travel long distances to meet;
2. Meeting with expertise, where it may otherwise be logistically impractical or expensive.

Table 1 compares immersion and collaboration of some molecular viewers.

Table 1. Comparison of molecular viewers

Molecular Viewer	Immersion	Local Collaboration	Remote Collaboration
JViewer	Yes	Yes	Yes
VRMol [9]	Yes	Yes	Poor
IMSVE [5]	Yes	No	No
VRDD [2]	Yes	No	No
Kinimmerse [7]	Yes	No	No
Gesture Based Tool [10]	Yes	No	No
AMMP-Vis [6]	Yes	Yes	No
Colaborative Jmol [4]	No	Yes	Poor
Distributed Pauling World [3]	Yes	Poor	Poor
MICE [8]	No	Yes	Poor

The comparison presented at Table 1 shows that just the JViewer offers immersion, local collaboration and remote collaboration features .

4 Conclusions

The teaching of Chemistry has found allies in Virtual Reality and in Collaborative Work, which offers immersion, interactivity and collaboration. The feeling of immersion is created by the output devices and by immediate response of user interaction. JViewer supports monoscopic or stereoscopic output devices and can be extended to a multiprojection system, as a CAVE [20]. The collaboration between dispersed researcher groups in JViewer is like a single-user program.

As future work, we plan to port JVIewer to run in a CAVE and add multimedia capabilities, including video and audio.

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Evaluation of Healthcare Institutions for Long-Term Preservation of Electronic Health Records

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Abstract. An evaluation of health institutions using the Trustworthy Repositories Audit and Certification (TRAC) is presented. TRAC is an audit methodology for information systems to evaluate its ability to preserve digital information securely over the medium and long term. With this methodology, different healthcare organizations in the metropolitan area of Barcelona (Spain) have been analyzed to determine their capacity for long-term preservation of the Electronic Health Records (EHR). From these results it is expected to propose a model of long-term preservation of the EHR. This paper concludes with lessons learned regarding the implementation of TRAC in healthcare organizations.

Keywords: digital preservation, audit, health organization, EHR, TRAC.

1 Introduction

This paper presents an ongoing work of the situation of different Healthcare Organizations in order to preserve their Electronic Health Records (EHR) on the long term. A survey was conducted in seven healthcare organizations of the metropolitan area of Barcelona (Mútua de Terrassa, Consorci Sanitari de Terrassa, Corporació Sanitària del Maresme, Consorci Sanitari del Maresme, Institut Universitari Dexeus, Grup Pere Mata and Grup SAGESSA). Since all of these organizations are private entities, they facilitate services to the public health network. All of them have a total of 25 hospitals covering a wide range of different specialties and population.

All entities analyzed were doing diverse initial processes or they are finalizing them. Processes are relative to the use of fully integrated digital EHR management within their Information and Communications Technologies (ICT) system. The first and most basic process is the conversion of analog data and paper health records into a digital format by digitizing processes. The second process is the development of an ICT system to manage EHR which are completely digitally born. The last strategy is the integration of the previously digitized health records with those created digitally on the computer system. Thus, all data will be digital objects to be managed by healthcare organizations, with different challenges such as electronic health records management or long-term digital preservation.

Due to this reason the minimum conditions to preserve digital information have been analyzed over these seven institutions. To carry out the study, it was applied the Trustworthy Repositories Audit and Certification (TRAC) methodology. TRAC [8] is

M.M. Cruz-Cunha et al. (Eds.): CENTERIS 2011, Part III, CCIS 221, pp. 136–145, 2011.

a qualitative methodology for information systems audit, designed to assess a repository to be trustful to retain information over the long term. To analyze the information system, TRAC analysis is divided in three areas as Organizational Infrastructure, Digital Object Management and Technology assessment. The TRAC analysis was performed by checking that there are appropriate processes running on to the organization or processes are clearly documented. TRAC result is a report that can detect improvement areas to get a reliable information system in order to preserve digital objects over time.

Once report advertences have been improved according TRAC guidelines it is possible to start designing a digital archive for long-term preservation or apply report enhancements onto the information system in the organization. Improvement applications report can also be carried out whether the repository exists. Open Archive Information System (OAIS), ISO 14721:2003 is a reference model to develop an archive to preserve the long-term records. OAIS reference model [11] does not define a particular technology, but emphasizes on both the information model definition and the Designated Community definition. The information model indicates how data to be kept is going to be represented onto the OAIS archive. The Designated Community is a system, person or agent responsible to receive and understand information to be retrieved.

EHR can be retained over the long-term by health care organizations through the use of TRAC audit and lately developing an OAIS model on its medical archive. Electronic health record is the health data representation of a patient to the course of his life. This data are represented by different expressions of data such as text, audio [1], graphics or video. According to Spanish law regulations, EHR must be preserved on the long term by an indefinite period of time. To accomplish this challenge, hospitals will have to organize processes in a near future in order to maintain long-term digital medical and research information. Institution analysis has been carried out through process assessment or documentation belonging to their clinical services documentation and archiving unit or their ICT unit. In some cases it was necessary to evaluate both units.

The document is organized into the following sections. Section 2 explains how TRAC can be performed, its relationship with digital preservation and EHR digital preservation implications. It also explains the methodology applied to healthcare organizations. Section 3 explains the results over the analyzed healthcare institutions that participated in the assessment. Finally, conclusions are exposed.

2 TRAC Methodology

2.1 Related Work

TRAC methodology is fairly new compared with other audit methodologies and there is a lack of published reports. However, some previous work on trusted digital repositories has been proved. Thus, the Network of Expertise in Long-Term Storage of Digital Resources (NESTOR) developed a catalogue for trusted digital repositories for long-term preservation, addressed to German cultural heritage organizations [3].

The Centre of Research Libraries has published two reports where two preservation audits have been performed. The first one is related to Portico Archive[1] a scholarly preservation service where its main objects ingested are journals, books and scholarly content. The second one is related with HathtiTrust[2] a large digital repository with more than 7.5 million digital objects ingested. Its primary objects ingested are digitized books. Both reports agree that Portico [9] and HathtiTrust [10] are trustworthy repositories to the general need of the CRL community.

It is also possible to find cases where TRAC is not only used for digital preservation but for other scenarios. TRAC is then applied to a repository that is not dedicated itself to digital preservation. In this case all the standards relating to audit of preservation [13] cannot be applied.

2.2 Performing TRAC Methodology

TRAC methodology was conducted to these entities through a survey and later interviews to different staff involved on the seven entities. Personnel involved in EHR management and archiving had different responsibilities and professional profiles, like ICT managers or medical archivists.

Trusted Repositories Audit & Certification: Criteria & Checklist (TRAC) is an audit qualitative methodology to be applied over a digital repository or an information system to retain information on the long-term. To do this, TRAC has indicators to be assessed onto the three sections mentioned above. All indicators use the vocabulary of the Open Archival Information System (OAIS) reference model, ISO 14721:2003.

This methodology is open enough about in reference to other rules that may help a repository to be trustful. This can occur in cases of special communities, as medical communities would be. Relevant standards such as ISO 9000, ISO / TS 21547:2010 or ISO 15489-2:2001, additional audits are tools that facilitate the audit with the TRAC methodology.

TRAC assumes that the main object to analyze is a repository where information is preserved or is going to be retained on the long term. It is also possible to apply TRAC methodology even whether a repository does not exist into the organization to be assessed. Therefore, TRAC result assessment is the conformance of a set of criterions to be analyzed. The conformance of theses criterions is verified by the existence of evidences, running processes or documentation. Repository has functions such ingest, management or access functions which prepare information for the Designated Community.

The Designated Community is a repository element responsible for receiving the information being retrieved to understand it without the need of technical support.

A digital repository is an information system that allows the preservation of long-term data through appropriate policies. Operations that can be performed in a repository can be started by data ingestion and can be finished on the retrieved information certifying that it is an exact copy of the original ingested. A series of intermediate steps will permit digital object management processes. There are several initiatives in repositories like DSpace[3] or Fedora[4] [7] where OAIS model has been implemented.

[1] http://www.portico.org
[2] http://www.hathiturst.org
[3] http://www.dspace.org
[4] http://www.fedora-commons.org

Such repositories have been widely used in digital libraries [6], but it is possible that a healthcare institution needs to apply another kind of technology also valid to long-term preservation. The reason is because it is possible that EHR management systems are technologically more advanced and possibly safer while DSpace or Fedora does not offer a complete solution preserving digital information. To carry out a repository analysis, TRAC analysis divides the information system in three sections. These sections are Organization Infrastructure, Digital Object Management and finally Technologies, Technical Infrastructure and Security sections.

All of three sections have a sum of 84 criterions to assess an organization. According to sections, Organization Infrastructure has 16 indicators, Digital Object Management has 44 indicators and Technical Infrastructure and Security with 16 respectively.

Organization infrastructure section emphasizes over legal or legislative mandates, regulatory requirements, structure and staffing organization, repository records retention strategy and financial sustainability. Although TRAC is in the process of becoming an international standard (ISO/TC20/SC13), many indicators in this section may be subjected to national law or Regulations.

Indicators belonging to the Digital Object Management section point on the repository ingest process, preservation strategies and the accurate information production and dissemination of the authentic versions of the digital objects. Assessment of this section is particularly relevant, because in order to be analyzed the structure and design of a preservation plan should exist. In case of a healthcare organization a preservation plan is the design of the processes involving the EHR long-term digital preservation. These processes range from the definition of the information model to be preserved to the design of the Designated Community or archivable information packets generation.

In the third section Technologies, Technical Infrastructures and Security indicators assess the audit over the technology adequacy, accuracy such as to detect bit corruption or loss. Security issues are also assessed verifying service continuity plan, risk assessment [12].

These indicators are verified by testing processes, analysis of documentation or analysis of evidences of the information system that belongs to the institution. After analyzing requirements for indicators information about the certification status and auditing of the repository is reported.

TRAC has also a minimum set of compliance indicators. These indicators are the minimum documentation or processes available that an institution who wants to keep long-term data should have. These minimum set of indicators, 6 belong to the Organization Infrastructure, 6 to Digital Object Management and 7 to Technologies, Technical Infrastructure and Security. Some of these indicators like those belonging to Organization Infrastructure section may be determined by the legal regulations in some countries and its verification can be more accessible. As mentioned earlier, according to TRAC guidelines it is not necessary to carry out the assessment to an organization without a repository for long-term preservation. However, there must be minimum conditions necessary to preserve information.

If the repository concept is applied to a healthcare institution, the repository would be part of the archive from a hospital. A hospital archive has active health records and passive health records. Active health records are those that their data are being updated frequently and therefore correspond to patients receiving care at the center. Passive records are not updated records over a reasonable period of time. In all the assessed organizations, an analog health record becomes part of the passive archive within 3 to 5 years on average provided they have completed the specific patient care. This situation suffers changes when the system becomes digital because information workflows and treatment is different. Currently, EHR are lying in the same computerized system all together being an active system constantly, but not necessary running under the same software. This means that interoperability through the standard HL7 is implemented to access EHR data [4]. This policy would have to be necessary changed as soon as the volume of information would be measurable in terms of Petabytes and information should have been kept in different silos separated from the active system. This situation may occur because the EHR have information attached such as DICOM radiographic images [5], documents in Portable Document Format (PDF), test information, audio, video and other digital elements. Therefore an EHR is a complex unit of information that requires different treatment in the long term, not as a single unit of information.

In any case, the concept of passive digital archive should not change whether a proper digital preservation planning [14] is done. However, changes in the concepts of ingest or retrieval information into the repository has to come about. EHR information to be preserved over the long term would be information that is already ingested and audited by the internal hospital processes. Therefore, this information already exists, is audited and should have the necessary elements for its preservation. These elements can be a metadata wrapper or another structure to identify information, according to the information model defined by the institution that retains the data.

3 Results

Due to the length of the data obtained, the analysis of the necessary minimum indicators will be presented. Analysis is reflected in three tables where rows are the assessed TRAC indicators and the columns (HC1 through HC7), the data belonging to the healthcare organizations processed to ensure anonymity for reasons of confidentiality. Table 1 shows the data of Organizational Infrastructure. In Table 2, data are corresponding to the Digital Object Management and data in Table 3 corresponds to the section on Technology and Security structure. As mentioned before, TRAC methodology consists on checking the evidences and documented processes of an organization. Thus, the result of TRAC assessment is the conformance of the correspondent indicator. This conformance is reflected in Table 1, 2 and 3 by a "+" sign. When criterion is not conformed or it was not possible to be assessed the result is reflected by a "-" symbol.

3.1 Organization Infrastructure Analysis

This section is responsible for analyzing the repository attributes affecting their performance. Thus, issues such as financial sustainability, preservation policies and strategies, were part of the objectives to be tested. Other aspects can be transparency in the documentation for the repository, regulations or international standards that also meet the information system, even without a direct connection with digital preservation, but whether it affects and organizational issues.

Table 1. Organizational Infrastructure minimum assessed indicators

Criterion	HC1	HC2	HC3	HC4	HC5	HC6	HC7
A1.2 Contingency plans, succession plans, escrow arrangements	+	+	+	+	+	+	+
A3.1 Definition of designated community(ies), and policy relating to service levels	-	-	-	-	-	-	-
A3.3 Policies relating to legal permissions	+	+	+	+	+	+	+
A3.5 Policies and procedures relating to feedback	+	+	+	+	+	+	+
A4.3 Financial procedures	+	+	+	+	+	+	+
A5.5 Policies / procedures relating to challenges to rights	-	-	-	-	-	-	-

Evidences examined in this section have been ICT strategic plans, training plans, staff development plans, missions and goals of the organizations and legislative requirements.

In Table 1 indicators A3.1 and A5.5 were not assessed. A3.1 indicator is associated to the definition of Designated Community and policies in place to dictate how its preservation requirements will meet. The reason for this result is that although the Designated Community by default will be the professionals who work for the healthcare institutions, there are no policies for long-term digital preservation planned.

A5.5 is an indicator that is not necessary compulsory to be accomplished by a healthcare institution as points over unclear ownerships / rights on digital content. It is clear that all information is generated by the healthcare institution. It is the institution who has the data ownerships. These data has been introduced on the Electronic Health Records, but patient has the right to access information to its own data.

The rest of indicators who are accomplished by all of them are related with ensuring the continuity of the information system (A1.2), acquisition of legal permissions required to preserve digital content over time (A3.3), quality assurance records (A3.5) and evidences of financial audits already taking in place (A4.3).

3.2 Digital Object Management Section Analysis

Digital Object Management section is responsible for analyzing all processes related to data retention processes within the repository. This means to evaluate the consistency of the digital data stored with the information model defined by the repository.

Ingest information management and recovery processes are also discussed in this section. The major part of indicators to be evaluated are all related with the functional entities of the OAIS model, ingest, data management, archival storage, administration, preservation planning and access. Concerning the minimum indicators, this section is the one where there are the most indicators to be evaluated. This section has a total of 13 indicators. Indicators to be evaluated are all indicators of the B1 section (B1.1 through B1.8). None of the entities met the requirements because preservation of passive records is not still planned.

Table 2. Digital Object Management minimum indicators rated

Criterion	HC1	HC2	HC3	HC4	HC5	HC6	HC7
B1 Procedures related to ingest	-	-	-	-	-	-	-
B2.10 Process for testing understandability	+	+	+	+	+	+	+
B4.1 Preservation strategies	-	-	-	-	-	-	-
B4.2 Storage/migration strategies	-	-	-	-	-	-	-
B6.2 Policy for recording access actions	+	+	+	+	+	+	+
B6.4 Policy for access	+	+	+	+	+	-	+

The main evidences conformed in this section have been processes involved on the ICT department like security processes or access policies.

In Table 2 there are just three indicators accomplished by the assessed institutions. As mentioned earlier, B1.1 to B1.8 are indicators related to the digital object workflows, preservation properties identification of each object or the use of the appropriate technology to correctly identify the digital objects to preserve. B2.10 is the indicator that has been experienced by all entities it is relative with process for testing understandability of the information content. The reason to be clearly accomplished is because current information is retained by individuals with discipline expertise. The Designated Community is also clearly well defined. Physicians or medical archivist are in charge of introducing or managing information. Indicator B4.1 is relative to the existence of documented preservation strategies or the evidence of its application. It is not professed because as metadata are generated in most cases by these healthcare entities, none of them generates preservation metadata, such as PREMIS [15]. B4.2 indicator is relative over the demonstration that a preservation strategy has been performed or the use of the appropriate metadata is done. B6.2 indicator is relative on the recorded actions on the access on the repository. The evaluation of this indicator has to be constant, because it depends on the institution to track user actions over the information accessed. All of these institutions track their users as a preventive action to avoid mistaken usage on their systems. According to this question, maybe some policies over tracking user would have to be modified.

The other accomplished point B6.4 is related to the access validation mechanism within the system. This means that, information stored should be accessed and being protected against deliberate or accidental damage. But in specific communities as health care communities are, the use of user credentials is important on accessed information to avoid access or personal data unprotected.

Since digital preservation of EHR is not yet planned in these institutions, most of these points are difficult to be accomplished. Another reason is that on their ICT systems there are active records while passive digital records no longer exist.

3.3 Technologies, Technical Infrastructure and Security Analysis

This section is responsible for assessing the safety and information integrity. It is also in charge of analyzing the technical structure that guarantees the security. Safety criteria used for digital preservation are similar to ISO 17799 and must be therefore considered. Evaluation of trusted and secure infrastructure is a common point to the security of an ICT system that a specific evaluation applied to digital preservation.

As it is noted on Table 3, the major parts of criterion are fairly accomplished by healthcare institutions. This result is partly to the legal requirement to these entities to have secure systems on managing EHR. Evidences examined in this section were technical specifications, security processes and ICT documented protocols.

Security structure form is similar to all of them because none of them had access outside the institution electronically. C1.7 indicator evaluates evidences or documentation such as hardware manufacturers, polices related to hardware support. Indicator C1.8 is relative to the accomplishment of having documented changes management processes. This means having documented process related to the six functional entities of the OAIS model as mentioned on the Digital Object Management section. Indicator C1.9 is relative to have documented processes for testing critical changes to the system. This means the replacement of software or hardware and its later monitorization. As this point just 5 entities get the result.

Four of the healthcare entities are succeeded over C1.10 indicator which is relative to react to software security updates based on a risk-benefit assessment. This means to have carefully documented any updates of the security software.

Relative to indicator from C2 section, appropriate technologies which are relative to technology watch, hardware or software inventory, most of the healthcare entities have these processes perfectly coordinated or are getting them.

Table 3. Technologies, Technical Infrastructure and Security evaluated indicators

Criterion	HC1	HC2	HC3	HC4	HC5	HC6	HC7
C1.7 Processes for media change	-	+	+	+	-	-	+
C1.8 Change management process	-	-	-	-	-	-	-
C1.9 Critical change test process	-	+	+	+	-	+	+
C1.10 Security update process	-	+	+	-	+	-	+
C2.1 Process to monitor required changes to hardware	+	+	+	+	-	+	+
C2.2 Process to monitor required changes to software	+	+	+	+	+	+	+
C3.4 Disaster plans	+	+	+	+	+	-	+

The last indicator, C3.4 belongs to the security section is related to the evidence of ISO 17799 certification, disaster and recovery plans of having a backup of the preserved information with a copy of the recovery plan. All organizations accomplished the requirements unless two who are doing modifications and by the time they were assessed, most modifications were being done.

4 Conclusions and Further Development

Our conclusions to this paper are lessons learned from assessing these healthcare entities. Analysis results are not very optimistic about the degree of development or current implementation of digital preservation processes since digital preservation is not yet a priority. Health care organizations will be affected by legal obligations in the near future. This fact will force them to develop new policies on data curation and making changes into their structures. These changes will suppose them a huge effort especially in hardware and software acquisition or staff training. Digital preservation is not yet a worrying problem while most institutions are still developing complete digitally born ICT systems using electronic health records. To have good results on assessment is essential to count on most people organization help. Understanding on the importance of digital preservation techniques and its implication over organization is also important. Organizational structure assessment in most cases comes by mandatory obligations or legal regulations. On evaluating the Digital Object section it is important to have at least a documented preservation plan to be assessed accurately. Relative to technologies, technical infrastructure and security section is the most probable section to be well assessed. The reason is that the importance of information to be kept in healthcare organizations is essential to their core business while information is active. When information is no longer active, it must be well preserved according to a preservation plan.

Further work resides on the application of a risk analysis methodology based on a recognized international standard emphasizing on digital preservation issues. Since there is an existing methodology [2], all aspects are not covered.

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Information Retrieval from Heterogeneous Data Sources: An Application for Managing Medical Records

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Abstract. Creating digital medical records and retrieve relevant information from them is a complex task. This complexity is given by the mixture of structured and unstructured information found in traditional medical records and that such information could be distributed in different data sources. The main contribution of this paper is the design of an architecture for an Information Retrieval (IR) system that integrates heterogeneous data sources, with a query interface in natural language. This system uses Natural Language Processing (NLP) techniques in order to transform the user query in subqueries to be executed on different data sources, profiting the query capabilities of Database (DB) and IR technologies. The system is connected to the MedlinePlus Medical Encyclopedia to extend the results obtained from a query showing relevant articles to it. In addition, a general application of this design is proposed to address the medical records management problem in a Cuban hospital.

Keywords: Information Retrieval, Databases, Heterogeneous Data Sources, Integration, Natural Language Query Interface.

1 Introduction

Today, information retrieval and its integration have assumed a completely different, complex connotation than what it used to be. The advent of the Internet, the proliferation of information sources, the coexistence of structured, semistructured, and unstructured data, all have added new dimensions to the problem. From the time of distributed DB leading to heterogeneous, federated, and multi-databases, retrieval and integration of information from heterogeneous sources has been an important problem for which there is not a complete solution. Techniques such as global schemas, schema integration dealing with multiple schemas, domain specific wrappers, and global transactions have produced significant steps but never reached the stage of maturity for large scale deployment and usage. Currently, the problem is even more complicated as repositories exist in various formats (HTML, XML, relational DB, Web DB with query-interfaces, etc) and schemas, and both the content and the structure are

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changing autonomously [1]. Thus, efficient IR systems become more and more necessary to obtain those documents that respond to a certain information need.

In this modern scenario of global information systems, a growing number of structured data sources (such as relational DB and repositories of XML documents) is evidenced that require a uniform query interface to access distributed data and mediate between heterogeneous data representations at different sources.

To interact with XML Information Retrieval (XML-IR) systems as well as DB systems, users must express their information needs in the form of a structured query. Traditionally, these structured queries have been expressed using formal languages such as XML Path Language (XPath) [2] and Narrowed Extended XPath I (NEXI) [3] for XML-IR and Structured Query Language (SQL) in the case of relational database systems (RDBMS).

Unfortunately, formal query languages are very complex and too difficult to be used by experienced and let alone casual users and are too closely bound to the underlying physical structure of the data source [4]. As a consequence, recent researches have conceived the idea of specifying the structural and content requirements implicit in the user queries using natural language.

An application to the problem of retrieving information from heterogeneous data sources using a natural language query interface came up in the construction of electronic medical records. The complexity of this problem is given by the mixture of structured and unstructured information found in traditional medical records and that such information is distributed in different data sources.

When working in the quest for automation, one approach is to structure all the information for the retrieval is made by traditional methods associated with the relational data model, which brings data loss and even non-acceptance by specialists. So, the application of IR techniques becomes essential to access those parts of medical records composed of free text. Therefore, the query capabilities of DB and IR technologies are profited through its integration to better meet the user's information needs.

A particular case of this problem is evident in a Cuban hospital. This center has a repository of information on autopsy records that are stored in a relational DB and XML documents with different Document Type Definitions (DTDs).

This paper describes an architecture for a IR system that integrates the query capabilities of DB and IR technologies to retrieve information from heterogeneous data sources using a natural language query interface. Furthermore, an application of this design is proposed in the construction of an IR system to address the problem of managing records in the already mentioned Cuban hospital.

2 Integrating Databases and Information Retrieval

The DB and IR are two areas of Computer Science that despite having large and successful development have evolved largely independently from each other. Both study concepts, models, and computational methods for managing large amounts of complex information. The DB community has mostly focused on highly structured data, and has developed sophisticated techniques for efficiently processing complex and precise queries over this data. In contrast, the IR community has focused on searching unstructured data, and has developed various techniques for ranking query results and evaluating their effectiveness, using text processing, statistical ordering models and user satisfaction [5-6].

There is now a rapidly growing awareness of the needs for integrating DB and IR technologies. From an IR viewpoint, digital libraries of all kinds are becoming very rich information repositories with documents augmented by metadata and annotations captured in semistructured data formats like XML, however the exploitation of the documents structure is a critical aspect of search on the Web. From a DB viewpoint, application areas such as customer support, product and market research, or health-care management exhibit tremendous data growth, in terms of both structured and unstructured information, so that the use of conventional DB is insufficient for proper operation [6].

A current research area where DB and IR techniques are integrated is the IR in XML documents. Such XML data inevitably exhibits heterogeneous structures and tags and, therefore, cannot be adequately searched using matching-based DB query languages like XPath or XQuery [7]. Often, queries either return too many or too few results. Rather the IR-style ranking paradigm is called for, with relaxable search conditions, various forms of similarity predicates on contents and structure, and quantitative relevance scoring. Ranked retrieval from multiple XML or other semistructured or even structured data sources may even be seen as a query-time approach to approximate information integration. Since the start of this millennium, significant research has gone into addressing these XML-IR issues, and the early approaches like [8] have meanwhile converged to a consolidated state of the art [9, 10].

3 Architecture of the Information Retrieval System

Dealing with structural diversity in heterogeneous sources has been a research topic in the DB field and in particular of data integration. The purpose of a data integration system is to provide the user the illusion of a single, integrated data source, on which the user can pose queries. Behind the uniform interface, the system will process these queries by translating them into the formats specific to each data source, processing them separately, and integrating the results into a single one [11].

About these premises, we assume that the information related to a certain domain is stored in a relational DB, XML documents with different DTDs and documents in plain text. The information in text documents appears in free text without any structure, whereas, in the relational DB as XML documents we find information in free text and structured information or data of attribute-value type.

Our goal is to build an IR system able to interrogate these data sources through a natural language query and obtain relevant results to that query into a single unit of information.

The above process includes a series of important issues that are addressed below.

3.1 Representation of the Information

The RDBMS traditionally have been commissioned to handle structured data and have improved storage techniques and access to them. However, they lack of powerful tools for text analysis that allow an efficient information retrieval in fields with textual information and an ordering of the results obtained from queries made, according to some relevance criterion. On the other hand, IR systems focus on their retrieval capabilities and query formulation and do not offer the efficiency of the RDBMS when the management of structured information and metadata is needed.

Considering the advantages and disadvantages that both technologies have to treat structured and free text information, our system divides it as follows.

- For each record in the DB, the information contained in attributes of type text (free text information), goes to an XML document with an identifier that allows unifying at some point the information that appeared in the original record.
- For each XML document, structured information goes to a record in the DB, as in the previous case, with an identifier that allows unifying at some point the information that appeared in the original XML document.
- The structured information in the DB, the information in free text in XML documents and the information in plain text documents are held in each of their respective data sources.

The main advantage of the integration of DB and IR technologies is given by exploiting their query capabilities using a RDBMS and an IR library of high performance.

3.2 Integration of Schemes for XML Information Retrieval

Traditionally, data integration operates at the level of schemas. A source schema characterizes the structure of each data source, and an integrated schema is provided to the user [11].

Given the assumption that XML documents have heterogeneous structures (various DTDs) it is necessary to integrate them into a unified structure. The result of the integration would be a unified DTD and a set of mappings from individual sources to this DTD. Therefore, a query can be expressed in terms of the unified DTD and get automatically translated to each of the data sources.

To accomplish the above process is intended to follow the methodology presented in [11] based on semantic models and inference techniques associated with them.

According to this methodology, the first step is to extract a conceptual model from each source. This process is straightforward: a concept for each type in the DTD is extracted, including elements and attributes, among which a distinction is not made.

Once a set of conceptual data source models are obtained, next step is to construct a unified conceptual model which characterizes all sources and mappings between each conceptual model to the unified one.

To build the unified conceptual model, groups of concepts (each one in different conceptual source models) that represent semantically similar data items are identified. This is a done semi-automatically, as follows. First, the names of concepts from different source models are compared for similarity, to identify potential matches. This is done automatically, with the help of the version of WordNet for the Spanish language [12]. Having identified clusters of concepts which potentially represent the same thing, one concept in the unified model is created for each cluster of source model concepts above a given similarity threshold; human intervention is required at this point in setting the similarity threshold.

Finally, the relationship between conceptual models of data sources and the unified model are extracted, adding a link between each source concept models and concept of the unified model derived from the group to which it belongs.

3.3 Natural Language Query Interface

Asking a question in natural language and getting a relevant answer is what the everyday user really misses in the process of IR. Moreover, as natural language is the best way so far to explain our information need, using it should help a system if the query is analyzed correctly. However, at present, NLP techniques are not developed enough to come close to the human perception of language, and actual results are not yet up to what we could expect.

In the case of "traditional" IR, where documents are considered as text only, classical search engines need a query composed of a list of keywords. Writing such a query is quite simple for the casual user, and the value added by NLP approaches is not worth the complexity of these techniques. On the other hand, many natural language interfaces for querying structured documents and DB have been developed, most of them transforming natural language into SQL [13]. This is probably because the benefits that can be gained in that case are much higher than in traditional IR. Indeed, SQL (and any structured query language used for XML retrieval as well) is hardly usable by novice and casual users. Moreover such languages impose to know the structure of the DB (or of the documents) [14].

XML retrieval stands between these two domains because it combines traditional features of the IR and the IR from DB. Since XML documents separate content and structure, XML-IR systems are able to return highly specific results that are lower than the document level. But, if users are going to take advantage of this capability in an operational (and possibly even in a laboratory setting) then they require an interface that is powerful enough to express their content and structural requirements, yet user-friendly enough that they can express their requirements intuitively [4].

Historically, XML-IR systems have used two types of interfaces: keyword based and formal query language based. Keyword based systems are user-friendly, but are unable to express the structural needs of the user. In comparison, formal query language-based interfaces are able to express users' structural needs (as well as their content needs) but are impractical for operational use since they are too difficult to use, especially for casual users, and are bound to the physical structure of the document.

The architecture presented in this paper proposes the design of an interface that allows the user to formulate her/his query in natural language. To process this query and retrieve documents or relevant information units from it, the following modules are introduced.

The first module analyzes the query posed to the system and returns two subqueries: one will be transformed into the query language SQL to be processed for the structured IR module and another will be transformed into the query language for XML, NEXI, to be processed by the semistructured IR module.

To transform the first subquery into SQL language, we intends to follow the procedures described in [13, 15], where it is proved that for a wide range of semantically tractable natural language queries, a mapping to the SQL language is guaranteed satisfactorily.

On the other hand, to transform the second subquery to NEXI, we intend to follow the procedures described in [4, 14, 16]. These works deal with different methodologies to extract the main parts of the query: structure and content using NLP techniques, and thus build a query in NEXI to retrieve information in XML documents.

Finally, the initial query is used in natural language to retrieve information from documents in plain text. Figure 1 shows a representative figure of this module.

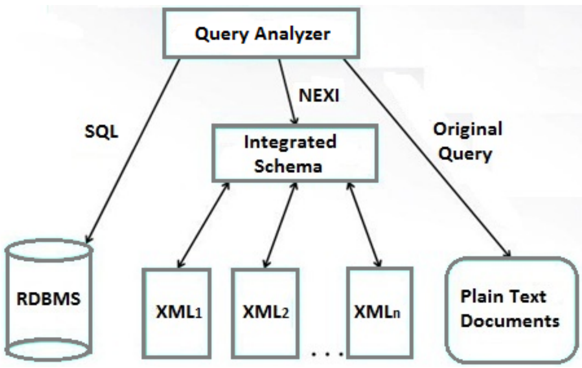

Fig. 1. Query analyzer module

3.4 Other Modules

Subqueries resulting from query analyzer module are the input for structured and semistructured IR modules. The former processes the subquery in SQL language with the help of a RDBMS and the second processes the subquery in NEXI with the help of a library for IR.

The merge module builds the results that will be presented to the user in response to the query. This module takes as input the information returned by the previous modules and combines them as follows: a set is formed with the documents represented by the records obtained as a result of the subquery made to RDBMS; on the other hand, relevant documents to the subquery in NEXI identified by the IR library are sorted in descending for its degree of relevance. The set of documents that are included in the overall results of the subquery in SQL, sorted by the degree of relevance awarded by the IR library, forms the final results set together with relevant documents identified in the plain text documents collection.

Finally, the presentation of the results module shows the user the query results.

4 An Application for Managing Medical Records

The Pathology Department of the already mentioned Cuban hospital has a large repository of information related to medical records of autopsies performed in it. Patient's personal data such as name, gender and dates related to the autopsy stands for structured data and appears together with long texts that stand for semistructured data and describe illnesses, treatments, review of systems, personal and family histories, among others. We call it semistructured data because even though this information is composed by free text, keeps a certain structure that is represented by the tags in the XML files. Both kind of information constitute a single medical record for a patient. This information is now stored in a relational DB and XML documents with different DTDs. Therefore, the IR becomes very difficult when it is not possible to transform all this data into a unified format.

Medicine specialists usually need information from this repository and especially check the fields that store the descriptive elements of the autopsies, both in the DB as XML documents.

First we must define a way of representing all information concerned to the practice of autopsies, and determine, based on the criterion of specialists in this area of medicine, those components that are relevant and through which they want to retrieve some information in the future.

Given the differences in the nature of the values that the fields mentioned above could take, we chose the model proposed in section 3.1 where for each data source, an RDBMS stores structured fields and semiestructured fields would be represented in XML documents. Together, they respond equally to a predefined structure for an autopsy. Thus, a patient's clinical history is divided into a record of the DB and an XML document, both with a common attribute that will unify all the information as it appeared in the register or XML document originally.

For this particular problem, self-describing structure of XML documents greatly improves the accuracy of the recovery, since the structural information can provide valuable clues to query, sort, and retrieve information. This includes giving the user the possibility of specifying structural constraints on what to search and what to get from a query formulated in natural language.

Table 1. Representation of clinical histories extract. The structured information goes to the DB and the semistructured one remains in the XML file.

Clinical History (a)	**Clinical History (b)**	
<name>P1</name> <gender>F</gender> <birth_day>18/9/1955</birth_day>	<name>P2</name> <gender>F</gender> <birth_day>14/3/1952</birth_day>	**structured information**
<CC>Headache</CC> <PI>For about 6 months has shown a growing problem of headache in the right hemicrania, throbbing, radiating to eye on the same side. Sometimes it is accompanied by vomiting and nausea. Recently, the headaches occur more frequently </PI> <medication>aspirin, 1 tablet every 8 hours </medication> <allergies>ampicillin, causes itchy</allergies> <smoke> About a pack of cigarettes per day since the age of 18 years </smoke> <FH>A brother, 61, has hypertension, another brother, 58, suffers from migraine, a sister died in infancy of unknown cause. Daughter, 33, suffers from migraine. No family history of diabetes, tuberculosis, heart disease or kidney disease, cancer, anemia, epilepsy, or mental illness. </FH> <ID>Migraine</ID>	<CC>Headache</CC> <PI> Patient refers headaches that have been intensifying over the past two months. They are located in the frontal region, accompanied by sudden vomiting and dizziness. Family members report that has conduct and personality disorder </PI> <medication>dipyrone </medication> <allergies>Not</allergies> <smoke>Not</smoke> <FH> The husband died at the age of 54 because of a heart attack. A brother, 50, suffers from migraine headaches. No family history of diabetes, tuberculosis, heart disease or kidney disease, cancer, anemia, epilepsy, or mental illness </FH> <ID>Tumor front</ID>	**semistructured information**

An example of query would be "search for all female patients over 45 who have been hospitalized for headaches with a family history of migraines". For this example, the clinical histories presented in Table 1 are relevant, however it is important to note that history (a) is more relevant to a query, so it will have a better order than history (b) when presented to the user as a result of the search.

4.1 Searching for Related Articles in the Medical Encyclopedia MedlinePlus

We supplement the results provided by the system, integrating it at a MedlinePlus Medical Encyclopedia [17]; so that, together with the results, the system shows to the user the relevant articles to the query obtained from the encyclopedia.

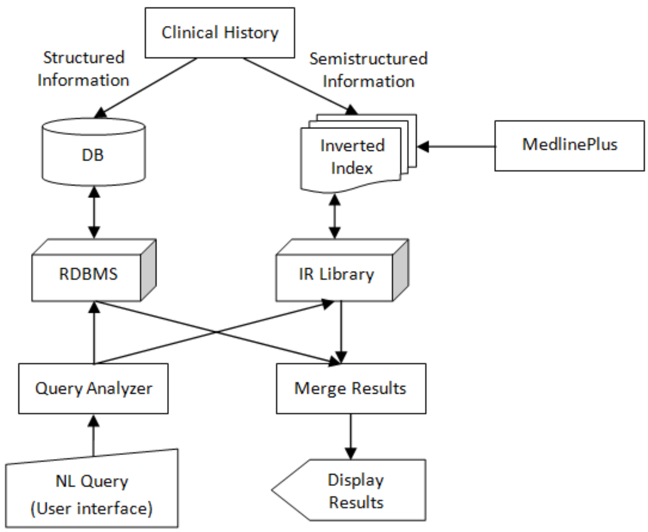

Fig. 2. Architecture of the IR system

This service expands the horizon of search in the system allowing not only the search at the autopsies information repository, but at this encyclopedia, a member of the National Library of Medicine of the United States, which is one of the most internationally recognized medical repositories, where health professionals can consult their reliable and updated content.

The remainder modules for this IR system follow the same procedure as described in sections 3.3 and 3.4. Figure 2 shows the design of the system architecture.

4.2 Validation of the Architecture

Currently, this architecture is being tested by means of the IR system developed for the Cuban healthcare institution, with the assistance of specialists in the field of medicine that could provide different criteria for assessing the quality of the system.

In order to compare the IR system, a test collection and other two systems could be built: one where the information of medical records is stored only in a relational DB and another where the information is stored only in a repository of XML documents; all the three systems could be evaluated taking into account the precision and the recall, that are the two most frequent measures for IR effectiveness.

Moreover, the system collects the queries made by physicians in their daily use, as well as the relevance judgments provided by them. This would also help to measure the satisfaction of these users and thus, having another variant to evaluate the system.

5 Conclusions and Future Work

This paper addresses the issue of integrating heterogeneous data sources for retrieving information from them.

Given the complexity of structured information and free text information management whose merger becomes an essential aspect of many existing information systems today, and the real possibilities to retrieve information from them, an architecture was designed for an IR system able to combine both types of information.

An implementation of this model was proposed for managing medical records of autopsies accomplished in a Cuban hospital. In this way, structured and free text information present in these records was integrated, profiting from the query capabilities of the DB and IR technologies.

This architecture could be exported to other scenarios that present similar characteristics and requirements, such as libraries, scientific repositories of information, etc.; and could be easily extended by adding the capacity to access other data sources depending on the context.

As future work we propose the automatic creation of user profile to provide greater accuracy in the transformation of natural language query to SQL and to NEXI. This information could be provided explicitly by the user, as well as learned from previous queries made and from the relevance judgments provided by them. It also aims to introduce relevance feedback mechanisms for the identification of similar results to one or more obtained in an initial search. This could take into account structural information when measuring similarity.

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Electronic Health Record in Dermatology Service

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Abstract. In this paper we describe the implementation of an Electronic Health Record in the Dermatology service of a Portuguese hospital. This system must follow the principle of simplicity, enabling recording quality and analytical processing. Standards and norms were also followed and it is shown that interoperability has a key role in the whole process. This project is a good example of cooperation between academic and healthcare institutions and shows the impact of new technology on healthcare organizations.

Keywords: Health Records, Interoperability, XML.

1 Introduction

Biomedical Informatics (BMI) is a multi-disciplinary area, which results from two main disciplines: Information Technology (IT) and the area of Medicine and Health Sciences The BMI is an issue of growing importance worldwide. The contribution can provide the modernization and improvement of the quality of delivering health services through better management of health information resources [1]. In the context of the need for management and organization of information, Hospital Information Systems (HIS) are arising. HIS can be defined as a subsystem hospital with a socio-technological development, which covers all information processing as well as the role of clinicians [2]. Its main purpose is to contribute to the quality and efficiency of healthcare. This objective is primarily oriented to the patient after being directed to health professionals as well as the functions of management and administration [3]. It is very important that a HIS is designed and implemented efficiently especially when it concerns the high quality of healthcare [3]. This implementation requires the existence of a management structure whose specific function focuses on the proper allocation of resources in order to ensure the efficient production of information [4]. Thus, the planning of HIS will cover, in a systematic way, each of the components in order to provide the complex clinical decision making capacity. In fact, if requirements of appropriate access to relevant data are not met, it becomes difficult to take decisions, diagnoses and other procedures resulting in fatal consequences for the patient. The HIS also assumes much importance in relation to costs since the sector of communication technologies in healthcare is increasingly important [3]. There are four basic functional processes, which the most important is healthcare itself. This process list

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begins with the patient's admission and ends in discharge or transfer to another institution. The other categories will serve to support the healthcare with the primary objective of improving quality. The four functional categories are characterized as follows: care; clinical process management; work organization and resource planning; and hospital management [5, 6].

The Implementation of this project's main objective was to provide a record with quality for the Clinical Dermatology Service in Centro Hospitalar do Porto, one of the major Portuguese hospital centre. This form of registration would have to take into account various factors including some that are general to any clinical records and other more specific to the dermatology. The registration form will need to ensure that it is visible and accessible to any clinician in order to solve the problem of misinterpretation of clinical information and promoting interoperability between people and systems.

2 Electronic Health Record

Electronic Health Record (EHR) is assumed as a HIS for excellence and has replaced the traditional manual recording in Paper Clinical Process (PCP). EHR may include all hospital areas with a need for registration information. This information can be clinical, administrative and financial [7, 8].

There are several definitions for EHR but in general this can be defined as the computerized records of patients' clinical data i.e. all information provided by demographic data, medical history, laboratory data, and more information sources. These data are inserted in an electronic system that enables the capture, maintenance, transmission and storage of clinical information which is essential, not only for the monitoring of the health status of each patient but also for purposes such as cost management [7, 9, 10]. Historically, first systems appeared in the 60's giving the first impulse of EHR in history, Although these early systems are not yet focused specifically on the clinical [11, 12]. In Portugal, the first breakthrough in the electronic record hospital came up with a system called SONHO. This system is geared to managing only administrative information. Currently, there are already systems in clinical information management the Medical Support System (SAM) and Support System for Nursing Practice (SAPE). There are also several implementations of EHR in Portugal but still with little dissemination [7].

2.1 EHR Functionalities

In order to facilitate and improve care in health establishments, the EHR performs some features, some of which are similar to the PCP. These features include: to maintain a history of each patient serving as a support assistance for the purpose of decision support or as a source of information for clinicians; to reduce the frequency of loss of records or record data as well as to reduce the occurrence of medical errors; to support communication between external sources of medical information, management and resource planning; to improve procedures for assessing the cost control. The main difference with operation of the EHR and the PCP is related to the interaction between several heterogeneous information sources. The linkage of information sources and the EHR is bidirectional; i.e. there is a feedback that does not exist for the PCP. Thus an electronic record in addition to containing the information set also allows the sharing of information among different users, as well as the interaction between information sources [9].

2.2 EHR Requirements

The success of EHR implementation depends on a set of requirements that must be considered. In hospital environment, the EHR have many common features with PCP but it should have a response, which must be fast, reliable and safe, It should be also accessible 24 hours a day. The structure of the EHR must allow seamless integration with existing HIS by promoting the ubiquity of records between different specialties and services. The ubiquity of the EHR will allow access to mechanisms for monitoring alarm systems and decision support. The electronic record will allow generation of documents and customized reports for specific purposes. It will become easier to configure interfaces for registration and more. The information contained herein must be standardized and uniform, and health professionals must be targeted by specific training [7, 13, 14].

2.3 EHR Advantages

Comparing with the PCP, the most advantage of the physical EHR is a small footprint device capable of storing an enormous amount of information. This advantage may still become more accentuated with the development of computer science [7, 15]. Another positive point is the duplication and sharing of information. This task becomes simpler and more immediate. This advantage enables the sharing of Clinical Process (PC) for different task synchronous implementation of clinical files to backup information and safeguarded the chance of loss and/or damage, which often happens with the PCP [7, 15]. Analysing the advantages at a structural level, the electronic record supports customizing the user interface, allowing the use of different layouts of insertion and viewing information under the very useful aspect of the availability of specific modalities in the hospital. The EHR also ensures the readability of data (it does not happen with the PCP, since the data are entered manually and their legibility depends on the handwriting of health professionals). At this level, another important advantage is that the EHR can perform the processing of continuous data, facilitating the detection of errors and issuing alarms in situations of possible pathologic abnormality. Finally, the EHR enables the automated collection of clinical parameters from monitors, imaging equipment, chemical analysis, among others [7, 15].

3 AIDA

AIDA (Agency for Integration, Diffusion and Archive of Medical Information) is a platform that consists of a Multi-Agent System (MAS) and overcomes difficulties in achieving uniformity of clinical systems, as well as medical and administrative complexity of different Hospital information sources [16]. AIDA was created by a group of researchers from the University of Minho, the Artificial Intelligence Group, and is currently installed at the Centro Hospitalar do Porto, Centro Hospitalar do Alto Ave, Centro Hospitalar do Tâmega e Sousa and Unidade Local de Saúde do Alto Alentejo. It is a good example of the successful cooperation between the University and hospitals. It is an electronic platform that provides employees with intelligence, the agents. This platform features a pro-active behaviour in its main functions: communication between heterogeneous systems, storage management and hospital information; response to requests in time; sending and receiving information from hospital sources like laboratories (labs) (medical reports, images, prescriptions, etc.). Thus, AIDA enables interoperability between hospital subsystems, assuming a main role where it is installed, as shown in figure 1 [17, 18]. It can be seen in Figure 1 that AIDA has an easy access for your users, allowing the management of clinical information anywhere in the hospital. In addition, the platform enables the sending of messages via phone or e-mail. The same way, AIDA establishes connection with all Systems of medical information: EHR; Administrative Information System (AIS); Medical Information System (MIS); and Nursing Information System (NIS) [18].

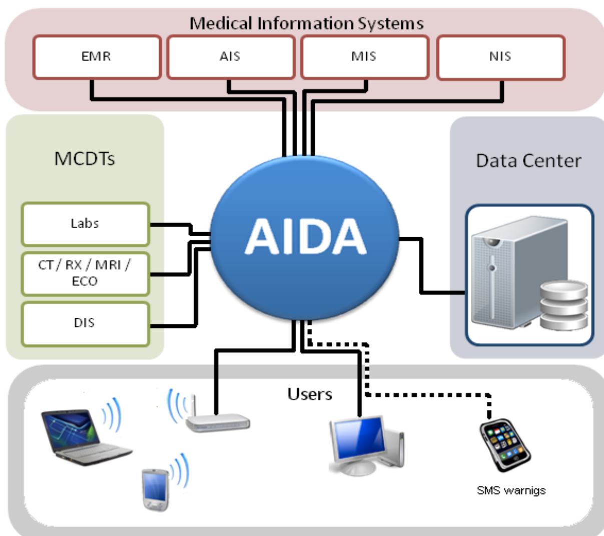

Fig. 1. HIS Structure

4 AIDA-PCE

The AIDA-PCE is a EHR and was implemented in the Centro Hospitalar do Porto. It is a subsystem of the HIS. The AIDA-PCE follows a problem-oriented organization suggested by Lawrence Weed in the 60's. This information organization is known as the Problem Oriented Medical Record (POMR) and it assumes that registration is a production of clinical scientific document. In this type of organization, clinical information (annotations, therapeutic, diagnostic) should be recorded for specific problem solving, creating a list of issues organized in a tree structure, where each new problem derives from the main branch [7, 10, 19]. One's note that problems can be classified as active or inactive, in which active problems are those where the disease is still active or even when intervention is required immediately. On the other hand, inactive problems require no urgent action. In AIDA-PCE problems assets are monitored and recorded daily using a SOAP (Subjective, Objective, Assessment and Planning) framework. Thus, each record contains the patient's symptoms, a doctor's observation, an analysis of diagnosis and a treatment plan that the patient is subject to [7, 19]. Figure 2 shows how the registration of clinical information is performed in AIDA-PCE. Looking at the figure, it appears that all the episodes begin with an admission form and finish with an outcome. An episode is the set of all operations for the patient, since the start of treatment until the end. Each episode is built upon an Integral Database (BDI), the Problem List, the Therapeutic Plan and subsequent records. It is noted that this register can be updated during the episode and along the evolution of the patient.

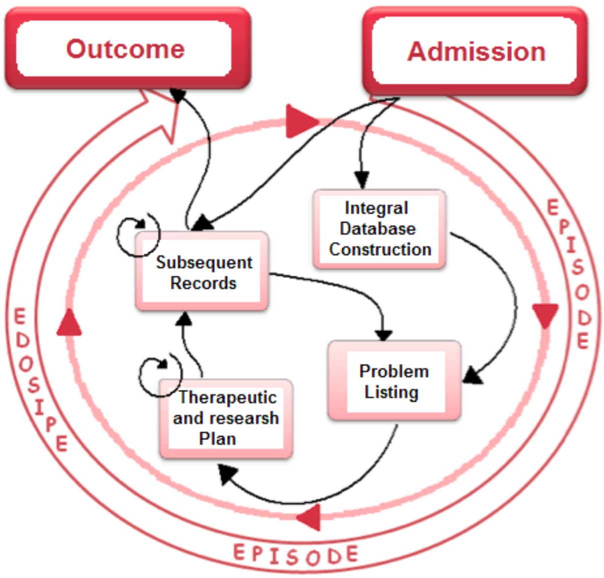

Fig. 2. HIS Structure

5 Normalization

One important property of AIDA-PCE is its interaction with different systems and the communication with biomedical devices. The information to transfer must be standardized and normalized. It is necessary that all data to be structured and misinterpretation to be forbidden. We must also take into account the database semantics, so information can be understood by different systems. In addition, the use of standards in the AIDA-PCE ensures the best communication between health professionals and interoperability between systems, allowing some automation in the hospital recording. The standards used in EHR are divided into three different purposes: standards for representing clinical information; communication standards; and image standards [7]. International

Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM), Systematized Nomenclature of Medicine-Clinical Terminology (SNOMED-CT) and International Classification for Nursing Practice (ICNP) are standards for classification of diseases and therapeutic clinics, where each therapy or disease is associated with a code recognized anywhere in the world. The use of these standards ensures that the EHR can be readable by any clinician in the world, also allows machines to interpret symptoms and can assist clinicians in making a diagnosis and treatment plan decision [7, 20]. As communication standards, the AIDA-PCE uses the Health Level Seven (HL7) as a protocol for exchanging messages, and web architectures and service-oriented architectures (SOA). HL7 protocol was created in order to solve the problems in the exchange of messages in the institutions providing medical care. In general, the HL7 defines an organized structure for the exchange of information, ensuring easy understanding of information by the recipient. This protocol also specifies that these messages are created and shared in extensible Markup Language (XML). This language has the peculiarity of being able to separate content and presentation format of the same information, thus, the same information can be accessed in different presentation formats and different media (computer monitor, PDA, phone, etc.) [7, 21]. SOA provides easy access for software specific functions and procedures.

6 Implementation

The big purpose of this project was to parameterize, structure and standardize the data to be inserted in the PCE. It was used the Service of Dermatology of the Centro Hospitalar do Porto as a service test. Several forms in XML were developed, to be used to insert, consult and manage data.

6.1 Implementation Process

The deployment followed an iterative process based on four phases: Information Gathering and Specification; Implementation; Testing; and Training. Previous literature searches and subsequent meetings with clinicians in the Department of Dermatology created the first phase, called Data Collection and Specification. Research led to the vocabulary knowledge and the general functioning of a dermatology department. The meetings with the physicians responsible guaranteed the collection of information on practices and methods used in this hospital service. The Implementation phase, or codification, was based on the digitization of all information collected by this stage, thus creating the forms in XML. The next phase, called testing phase, has proved to be of great importance to the whole process. At this stage, all forms were submitted to various tests, at a computer level, and testing of clinical level, where it was evaluated the functionality of the forms under a health professional point of view. The first tests were carried out by a form designer and served to correct function errors. The next tests were performed in the presence of medical professionals involved in the project. The latter tests allowed significant corrections at the level of form performance in hospital real time, thereby generating a mini-cycle between the second and third stages. After approving, it was performed the last stage of the process, called the Training. This phase consisted of training and presentation of the new registration method to all clinicians in the Dermatology Service. Figure 3 shows the implementation process adopted in this project.

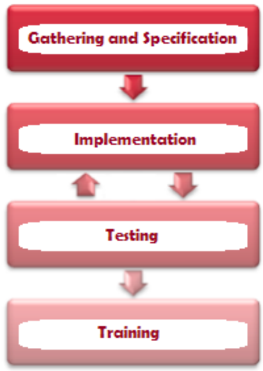

Fig. 3. Phases

6.2 Concerns in the Construction of Forms

A major concern of the implementation team was the constant insistences of monitoring health professionals across the implementation process. The routines used everyday by clinicians cannot be changed too much. In the same way, this monitoring allows for a greater familiarity between clinicians and the electronic record. So each form contains only useful information to clinicians in the specific task it performs. Another big concern of the project was the standardization of clinical terms, eliminating ambiguity in information exchange. The list of parameterized data was based on ICD9, system adopted by the Portuguese government. Two more concerns taken during the construction of the forms were the largest possible parameterization of the data, reducing the free text fields, and greater use of combo boxes instead of checklists. The greatest possible reduction of free text fields reduces the time spent by clinicians in completing the forms and facilitates further data analysis for comparative studies and statistical data. This preference proved to be important, since the service in question produces annual control statistics. Combo boxes preference is justified by the fact that the checklists have several interpretations to the clinician. With combo boxes one and only one selection is made.

6.3 Structure Forms

The structure of forms can be divided into three distinct parts. The first part contains patient reference and admission information; such as reasons, history of the disease, personal and family history, among others. The second part of the structure can be called the body of the form. This part contains more specific information of each service involved. In the case of this pilot service, there is greater information on the dermatology department. In this project we can find a third part that is related to the destination for the patient at the end of the medical act. Here are fields such as plan, destination, next appointment, among others.

6.4 Inteoperability

The forms follow other characteristics that are of great importance to facilitate and assist the work of clinicians. The forms allow to import data that has been previously saved in PCE and import data from other subsystems (SONHO, SAM, laboratories). Another particularity of the forms is the function to perform calculations and arithmetic operations (for example, to calculate the Body Mass Index (BMI)). These forms allow fro using pre-loaded texts, when the doctor prepares a report with fields filled in by default. The forms allow for assigning scores to the state in certain patient evaluations. As a rule, the clinician classifying the patient's condition in many ways and forms returns the value of the final score providing the current status of the patient. This feature was used to assess the patient's physical status.

7 Conclusions and Future Work

In this paper we presented a solution to adopt health records in a Dermatology service, as an pilot service. The main goals are to improve the quality of information in order to support the patient problem solving and the development of clinical research through the use of historical cases. The use of EHR is now a reality in the Centro Hospitalar do Porto, one of the Portuguese major public hospital centre, being mandatory the use of AIDA-PCE in the hospital. The project followed the principles of simplicity, using normalization and terminology.

Based on the success of this implementation, the next step will be to extend this work for all services of the Centro Hospitalar do Porto and other health institutions.

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Specifying Time-Out Points in Surgical EMRs–Work in Progress

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Abstract. Workflows for surgical procedures have built-in time-out points to minimize occurrences of unintended faults and omissions during surgeries. They have been recommended in the best practices of appropriate surgical sub-specialties, as well as the Joint Commission. At these timeout points, designated team members perform recommended precautionary measures, such as verifying the accuracy of implants, to ensure unintended mistakes are not made before proceeding to the next stage. These precautionary measures are usually recorded in paper-based checklists and retained for a stipulated period of time. We show how these timeout points can be specified as formal workflow requirements in surgical Electronic Medical Records (S-EMRs).

Keywords: Surgical EMR, Time-out points, Surgical Errors.

1 Introduction

Due to technical advances health care procedures and workflows are becoming more complex [1], and surgical sub-disciplines are no exception to this trend. In such complex workflows, avoiding procedural errors, including incorrect diagnoses as well as medical errors and other sources of avoidable complications [2], contributes to improving quality of medical care received by patients. Wrong patient, wrong site, wrong side, wrong implant, retained sponges, unchecked blood transfusions, mismatched organ transplants are all examples of surgical errors which decrements quality of surgical care [3]. Although patient safety is taken into account when performing surgeries, all current studies show that surgical errors continue to be a significant challenge to high quality surgical care. For example, 98,000 people die annually due to medical errors [4]. A more recent study estimated that 5 to 10 of these unexpected events occur daily in the United States based on the database analysis [5].

In our paper, we suggest a methodology to study surgical safety issues in the now accepted Use Case – Misuse Case paradigm for the Requirements engineering. To the best of our knowledge, there is no formal definition or characterization of kinds of Time-out Points of a surgical Electronic Medical Records (EMRs) system, which we provide. Additionally, we also propose a potential specification and enforcement model of a workflow in surgical EMRs.

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The rest of the paper is written as follows. Section 2 reviews related work. Section 3 provides an overview of our surgical workflow models and the insertion of time-out points into the workflow. Section 4 introduces our method of specifying time-out points within the workflow. Section 5 describes a case study of inserting time-out points into an existing surgical workflow. Section 6 describes how we can move some "show-stopping" time-out points as early as possible in order to avoid abandoning the procedure at later stages. Section 7 concludes the paper.

2 Related Work

Surgeries are complex procedures that require the cooperation of many actors with numerous sub-procedures. Some institutions, medical practitioners, and researchers devote themselves to reducing preventable deaths and complications in surgery, including designing and enforcing surgical safety checklists [6-8], new policies, guidelines, and standards [9, 10] to govern surgical procedures. The World Health Organization (WHO) developed a checklist to ensure the safety of surgical patients worldwide [11]. The Joint Commission approved the Universal Protocol for Preventing Wrong Site, Wrong Procedure and Wrong Person Surgery, which became effective July 1, 2004 for all accredited hospitals, ambulatory care and office-based surgical facilities. However, mistakes still occur and in addition, cultural factors also act as a barrier to implementing surgical checklists [8].

Many healthcare organizations have already employed computerized devices and/or computer systems for improving patient safety. These medical systems include Context-aware systems for the Operating Room (OR) [12, 13] and Workflow-driven information management systems that help healthcare providers in reducing communication misunderstandings and coordinating work.

The 'Context-Aware Peri-operative Information system' [12] can use many monitors and sensors collect OR data, that are analyzed using a rule base and displayed on an OR-Dashboard to help healthcare providers detect complex surgical events, and document these events in EMRs automatically. The 'Context-aware Patient Safety system' takes patient safety concern to a higher level by extending others' previous work, providing additional safety-critical contextual reasoning, and by utilizing information about the accuracy of contextual data [13]. These technologies allow systems to improve the overall surgical care quality by monitoring key attributes. However, some researchers have argued that context-aware computing is error-prone and sensors such as RFID readers have high failure rates (false positive and false negative). False readings at best cause stress and annoyance to the healthcare providers, and at worst could be harmful or even fatal to patients.

In recent years, different kinds of workflow management techniques have been used in the medical field. Workflow-based systems help in diagnosis of disease, assist in medical decision making, optimize scheduling medical events, such as OR, and aid in therapy [14-16]. Surgical Workflow predefines surgical procedures, in which documents, information or tasks are passed from one healthcare giver to another based on procedural rules [17]. The significant benefit provided by using workflow into a surgical management system is delivering systematic management among surgical processes. It can also be used for qualitative reviews of the procedures and outcomes.

3 Time-Outs in Workflow-Based Surgical EMR Systems

An EMR of a patient includes his/her complete medical information, such as medical history, diagnoses, allergies, treatment plans, consents, etc. During a surgery, all or part of such patient's information will be used and/or updated. The challenges, however, are how to retrieve information completely whenever needed, and how to ensure that information transferred between healthcare providers are accurate and relevant. Surgical workflow processes have well-designed sequence executable tasks. Each task needs different patient information; therefore, a workflow-based surgical EMR system allows required information to be retrieved automatically when a task needs them. However, existing surgical support software is not robust enough to alarm on all potential human errors that could occur during a surgical procedure. A time-out point is one in which the whole surgical team in attendance stops all other tasks and checks a pre-defined condition before proceeding to the next step.

Definition (Time-out Point): A time-out point is a triple < Condition, Type, Alternatives> where the three components are defined as follows:

- Atomic condition:= [attribute_value] [comparison operator][attribute_value] | value [comparison operator] attribute, where comparison operator:= $\{=, \neq, <, \leq, >, \geq\}$
- Condition:= Atomic condition | condition [Boolean Operator] condition, where Boolean Operator: = $\wedge, \vee, \neg$
- Type: non-detrimental , detrimental
- Alternatives are a non-empty, prioritized list of actions. If the type is non-detrimental, then the last action is "Record all attributes of the condition and proceed to the next stage". If the type is detrimental, then the alternatives list is empty.

The previous definition formally captures the essence of a time-out point. The first component, condition, specifies a check that is inserted in order to prevent one or many errors or omissions. This condition is a Boolean combination of attribute value comparisons constructed out of some attributes that could generate an alarm of a potential error or omission before it occurs. The second component, type, takes the value of non-detrimental or detrimental. The distinction is that the condition stated in a detrimental time-out point must be satisfied in order to proceed to the next stage of the workflow. If not, the rest of the procedure must not occur. The third component is a list of prioritized alternative actions that can be taken if the condition fails at a non-detrimental time-out point. The last alternative on this list says that if all other alternatives fail, to record the attribute values used to specify the condition and to proceed to the next stage.

There are two objectives to having time-out points. The first is to ensure that there are sufficient time-out points inserted to ensure that all conceivable Misuse Cases are covered and that the time-out points are appropriately categorized as detrimental or non-detrimental. The second objective is to ensure that checks performed during a detrimental time-out point can be done as early as possible in the workflow.

In our approach, we combine time-out point enforceable surgical workflow with a Clinical EMR system (C-EMRs) to create a more robust S-EMR model. Our model consists of: User Interface (UI), Time-out Point Manager (TPM), Workflow Engine (WE), C-EMRs. Fig. 1 shows the architecture for designing our proposed time-out point enforceable workflow-based S-EMR systems.

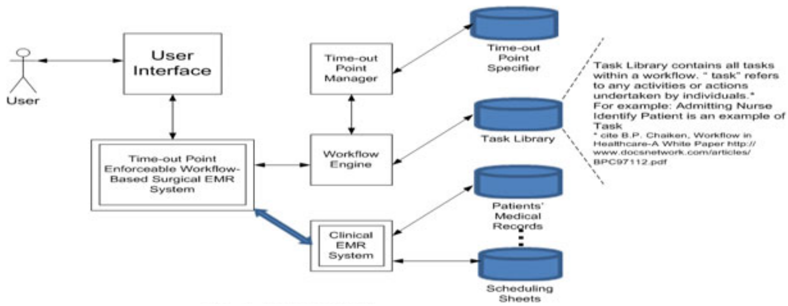

Fig. 1. Architecture

- Users are humans who interact with the system, such as surgeons, nurses, anesthetists, patients, etc. Patients have the right to view surgical logs in case they want to audit their own surgical procedures [18] and the quality care team also may want to review the logs.
- WE controls the process tasks of a workflow, triggers other cooperating systems to retrieve required information, notify or alarm users to interact with the system or to follow standard procedures.
- TPM is an additional control to the surgical workflow. It ensures that time-out points are enforced before proceeding to the next stage of the workflow process.

Users log into the S-EMR system based on their assigned roles in a surgery. The first task within the surgical processes notifies the user to interact with the system. For example, a nurse fills out a form or clicks a command button. Then the S-EMR communicates with TPM and triggers cooperating systems, such as C-EMRs, to retrieve needed information (if the task requires them), to check if previous task has satisfied the measuring criteria. If satisfied, the next task will be active upon completion of the current one.

For example, when a patient checks in or before being transferred from the ward, the admitting nurse (role) will fill out a patient identification form. After verifying the information with the patient verbally, the nurse submits the data that will be stored in a log file. In our system, time-out points are points in which systems check for a condition. The system will retrieve patient information from C-EMRs, and compare it with information submitted by the admitting nurse (role). If the information matches, a wrist band with a barcode will be created. Otherwise, the admitting nurse (role) will receive an alarm. If the identification check fails, the nurse may be required to (1) check with ward/clinic that sent the patient, (2) surgeon, (3) anesthesiologist, (4) the internist records of the pre-operative examination, in order to avoid taking the wrong patient into the OR. Doing this check will prevent taking the wrong patient into the OR.

4 Selecting Appropriate Time-Out Points within a Workflow

Retrospective studies [18] and prospective studies [19] are used to analyze the root causes of surgical errors. Seiden S. and Barach P. in their research paper

'Wrong-Side/Wrong-Site, Wrong-Procedure, and Wrong-Patient Adverse Events (WSPEs)' [20] say that the main reasons cause WSPE are 1) patient and procedure factors, like similarity of site, surgery, and patient names; 2) breakdowns in communication and teamwork; 3) failure to comply with safety checks and standards. The workflow-based S-EMR system has the capability to eliminate errors that are caused by above three reasons. However, where checks or enforcements should be applied in a surgical workflow could be a new challenge faced by developers. We introduce a methodology to select appropriate time-out points within the workflow by adopting the use/misuse cases [21, 22] to analyze possible intended and un-intended malpractices.

Use Case (UC): Surgeon uses sponges.

Misuse Case (MisUC): Surgeon leaves a sponge in patient's body.

Mitigating Use Case (MitUC): In order to prevent a surgeon leaving a sponge in a patient's body, two additional actions are taken. When sponges are introduced into the sterile field, we defined them as entering sponges. In contrast, when at the end of procedure, used and unused sponges are exiting sponges. The following actions are in the MitUC: (1) Circulating nurse counts entering sponges; (2) Scrub nurse counts exiting sponges; (3) If the counts are equal then proceed to the next step; (4) Otherwise, proceed to execute remediating treatment in order: (A) Search around for sponges, such as on the floor, in the trash can, etc. (B) take an X-ray of the patient's surgical site to confirm that no sponges are left inside the patient's body. (C) If neither works, record the failure and proceed to the next step of the workflow.

Time-out points set conditions to be checked before proceeding to the next stage. As the example shows, we will set two time-out points at before the operation start and at the end of operation but before the patient's body is closed.

Time-out point at the end of operation: {entering sponge count = exiting sponge count}, if true, proceed to the next step in task of workflow.

Type: non-detrimental

Alternatives:

(1) Search surgical site, such as on the floor, in the trash, etc.
(2) Take X-ray for radiological confirmation that no sponges are left.
(3) If all entering sponges cannot be accounted for, record the count mismatch and proceed to the next step.

} Alternatives

This time-out point is one of the non-detrimental time-out points, because the surgeon will proceed to close the open wound after all checks fail and proceed to the next stage. Furthermore, notice that we cannot add any more checks to the beginning of the surgical procedure to improve surgical safety, because the final sponge count is not available before this stage.

5 An Example Surgical Procedure

In this section, we discuss the specification of workflow that implements a sample (eye implant) procedure for cataract surgery. We use TP-n as the notation for the n^{th} time-out point. Fig. 2 shows a timeline described by an eye surgeon.

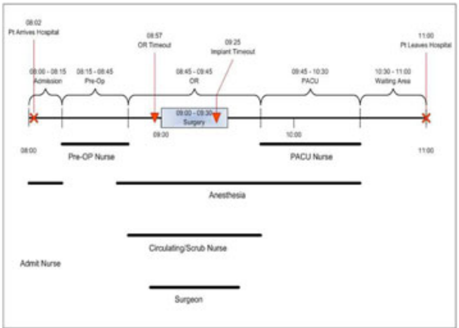

Fig. 2. Sample procedure Timeline (original)

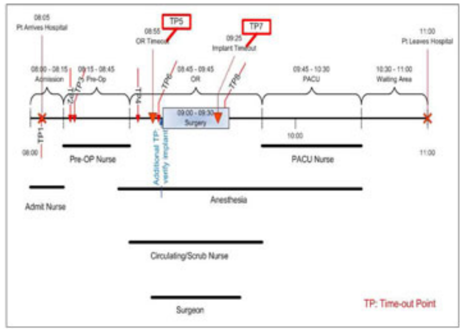

Fig. 3. Sample procedure Timeline (after analyzing, adding more TPs)

The surgical workflow (Shown in the Appendix, Fig.4) starts when the Admitting Nurse (role) identifies the patient in the EMR system upon arrival at hospital. We set our first time-out point, or TP-1, at the beginning. At this stage, in order to pass the TP-1, the identifying information needs to match the information in C-EMR. Once the patient is identified, the workflow proceeds to the next stage of wheeling in the patient. If the comparison does not succeed, the Admitting Nurse (role) has to communicate with clinic staff to recheck the patient, if the patient is not the right person, the surgical procedure is canceled.

Then the Transport Technician (role) helps transfer the patient to the pre-operative holding area. The Pre-Op Nurse (role) identifies the patient in the S-EMR system upon arrival. This is our second time-out point, TP-2, in our model. At this stage, in order to pass the TP-2, the identifying information needs to match the information in the surgical log in S-EMR and the information in C-EMR. If the comparison does not match, the Pre-Op Nurse (role) has to communicate with the Admitting Nurse (role) to re-identify the patient, and again if failed, the surgical procedure is canceled. Additionally, the Anesthetist/Anesthesiologist (role) may also meet the patient in the pre-op area to verify any allergies and medications, and may again, re-verify the surgery. It is the third time-out point, TP-3. The verification information needs to match information in C-EMR, in order to pass TP-3. The Anesthetist/Anesthesiologist (role) communicates with clinic staff to verify related information again, if failed, for example this is a wrong surgery, and the alternative would be to cancel the surgery and document it in the surgical log. After Passing TP-2 and TP-3, the patient is ready to be transported to the OR.

The Circulating Nurse (role) helps prepare the OR - places the sterilized instrument tray and other equipment into place. The Scrub Nurse (role) unwraps instruments placed on the sterile tables by the Circulating Nurse (role). Both of them are required to count "sponges and instruments". We set the 4th time-out point, TP-4, right here. At this stage, in order to pass the TP-4, the checking information given by Circulating Nurse (role) needs to match Scrub Nurse's (role). If the counts does not match, the nurses are required to recount. This is a non-detrimental time-out point. Then the Surgeon (role) sees the patient in the OR. The Circulating Nurse (role) will read the patient's name, type of surgery, side of surgery before the Anesthetist/Anesthesiologist gives the patient pre-operative sedatives. This is TP-5. Before the surgeon drapes the patient and proceeds with the surgery, all information about the surgery read by the Circulating Nurse (role), should be reconfirmed by the Circulating Nurse (role), the Scrub Nurse (role) and the Surgeon (role); it also should match the information in the C-EMR. This is a detrimental time-out point. For minimizing any error at this stage, the surgical team should carefully deal with Time-out Points 1, 2, 3. The next time-out point, TP-6, will be the above Surgeon (role) checks the marked site/side. The patient's last diagnosis image retrieved from the C-EMR is shown on a screen in OR. In order to pass TP-6, the marked side must match the information on the image. If passed, the Surgeon (role) starts the surgical procedure. The Scrub Nurse (role) assists the surgeon by handing instruments, sutures, implant(s) to the surgeon when needed.

The Anesthetist/Anesthesiologist (role) monitors the patient's vital signs throughout the procedure. This monitoring information is automatically stored in a surgical log. If a surgery includes an implant, the point of asking for the implant is the TP-7; the implant type, power, etc. is verified from the records and repeated by the Surgeon for verification. If they do not match, the alternatives are 1) Get new implant; 2) if new implant is not available, cancel surgery, report it in surgical log. This is a detrimental time-out point. At the end of operation, TP-8 occurs. The Circulating Nurse (role) and Scrub Nurse (role) count "sponges and instruments". They count separately and compare with each other. Unlike TP-4, it is possible that this post-surgical/exiting count will not match the pre-surgical/entering count. Detailed information is described in the last section. At the end of the case, the patient is transported to the Post-Anesthesia Care Unit (PACU).

The Circulating Nurse (role) may also help the Transport Technician (role) transport the patient to the PACU after the surgery is completed. The PACU Nurse (role) accepts the patient upon arrival, monitors the patient during the recovery period, and reports any concerns to the anesthesiologist. The PACU Nurse (role) will document patient status, drinking fluids, vomiting and other clinical observations necessary for discharge. Once the patient has recovered, the PACU Nurse (role) will discharge the patient from the PACU. Discharge orders from the surgeon would determine what happens next as well as follow-up instructions. Because we have analyzed a non-detrimental time-out point in the previous section, we now show a detrimental time-out point TP-7. Here the implant will be checked for the compatibility before the surgeon inserts it into the eye of the patient.

Condition: (Observed_implant type = prescribed_implant_type)

Type: detrimental

Alternatives:{1. Get new implant}

Here the attribute Observed_Implant_type is observed by the surgeon and/or the circulating nurse. The variable prescribed_implant_type can be obtained from the C-EMR. This time-out point says that if the implant types do not match, then abandon the surgery. Although this time-out point is a detrimental one, checking that the available implant is type compatible with the precribed implant type could be moved to the beginning of the surgical procedure, because values of both attributes are available at that time. Thus we can either move this time-out point to the beginning of the surgery, or insert the same time-out point at the beginning of the surgical procedure.

6 Moving Detrimental Time-Out Point as Early as Possible

In this section we informally describe an algorithm to move the detrimental time-out points as early as possible. Our algorithm is as follows:

1. For each detrimental time-out point, get the stage, say E of the workflow, where all the variables of the condition are instantiated.
2. Create a time-out point at E and assign the same actors the responsibility of checking the condition of the new time-out point.

This algorithm can also be optimized by combining the conditions of multiple detrimental time-out points at one point of the workflow. This way all "showstopper" issues can be addressed at an early stage. Because attending to time-out point also consume valuable time during the surgery, combining them would save having multiple stops in the workflow. Another possible optimization is to verify if the condition of a time-out point logically implies the condition of a timeout that occurs later in the workflow, because in that case (unless the attributes change between them) then the later time-out may be safely removed because of the earlier one. This analysis would require a more detailed specification and an analysis of variable mutability during the workflow, which we are addressing.

7 Conclusion

In this paper, we presented a framework of time-out point enforceable workflow-based surgical EMR system. In order to do so, we formally defined a structure to specify time-out points and categorized them as detrimental and non-detrimental. Because it can stop a surgery in the middle of a procedure, we proposed how they can be moved to an as early as possible point in the surgical workflow. We also suggested how detrimental time-outs can be combined to minimize the time taken to address them during a procedure. Although time-out points are inserted in order to minimize errors and mistakes, they also consume valuable surgical time and cause the whole team to stop all other work and perform these checks. This procedure elongates the total time of the procedure, which results in the patient being under anesthesia for a longer time, distracting the surgical personnel and consuming valuable OR time. In our ongoing work, we plan to investigate these tradeoffs.

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Appendix: Surgical Workflow in YAML

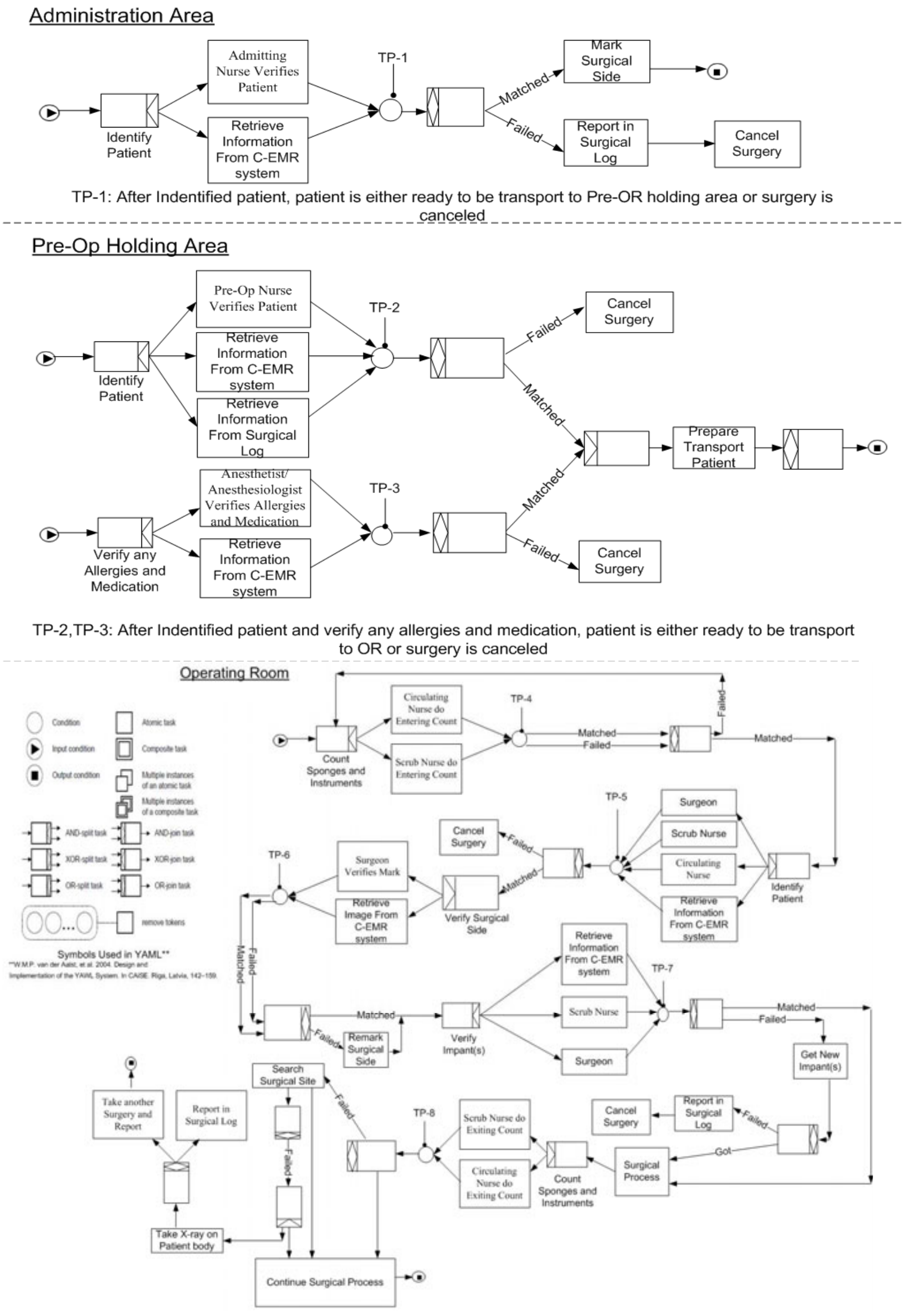

Fig. 4. Workflow of the Example Surgical Procedure

The Scenario-Oriented Method for Recording and Playing-Back Healthcare Information

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Abstract. This paper proposes a new method, called the *scenario-oriented method*, to support the idea of recording and replaying the healthcare information such that the reporting and decision-support capabilities can be enhanced. In order to play back the changing history of certain information units, the scenario-oriented method attempts to organize related information and knowledge elements as a *context* so that the history of real medical activity can be recorded, and then be queried as a continuous, on-the-fly, understandable and playing-back information scenario through replay operations.

Keywords: Scenario-oriented, Replaying, Healthcare.

1 Introduction

Due to the increasing demand for reduced cost and improved quality of service in healthcare, the computerization of *Clinical Practice Guidelines* (CPGs) has been promoted. For computerized information systems implemented to manage such *CPGs*, a key goal is to facilitate the process of retrieving specific information unit so as to review its whole changing history, such as, replaying a medical patient plan produced during the treatment of disease according to certain clinical guidelines. The *replaying* ability enhances the reporting and decision-support capabilities in the organization. Current large-scale information systems are designed to support the general queries (e.g. querying relational data, or retrieving parts/whole of documents, etc.) and lack of the ability to review the history information. As a result, users are often unable to obtain the history of a desired specific information unit within a well-defined subject area. This fact led to the proposed approach in this paper so as to enhance the specific querying capabilities (replay) of computerized information system.

This paper proposes a new method, called *scenario-oriented method*, which attempts to organize/reorganize all medical information and knowledge elements that would constitute a meaningful domain information scenario such that the real medical activities can be recorded and then replayed dynamically in future. One of the benefits of this method is that users can effectively view the day-to-day medical activities as a continuous, on-the-fly information scenario through a *Replay Scenario* statement, which combines a query-response approach and information visualization techniques.

The rest of this paper is organized as follows: Section 2 presents the related work. Section 3 gives an overview of the scenario-oriented method. Section 4 gives a Microalbuminuria Protocol (MAP) case study. Section 5 outlines an implementation architecture to realizing the scenario-oriented method. Section 6 concludes this paper.

M.M. Cruz-Cunha et al. (Eds.): CENTERIS 2011, Part III, CCIS 221, pp. 175–184, 2011.

2 Related Work

Since 1980s, research in Human Computer Interaction (HCI) has used scenarios as representation of system requirements to improve the communication between developers and users [1]. There is a great variety of scenario usages in many different disciplines. One typical usage is scenario-based information retrieval, which has been extensively explored in the field of seeking information from medical text [2,3,4,5]. In retrieving medical text, users are often interested in answers relevant to certain scenarios, scenarios that correspond to common tasks in medical practice. Current information systems do not provide efficient way to fulfil this requirement.

Facing with this challenge, Becher et al. [2] presented a user interface of summarization system for physicians in Bone Marrow Transplantation. The interface has users' state well-articulated questions that serve as summarization target and basis for retrieval queries, and it displays summarization results in an organization that fits the user's situation. A scenario forms with intermediary structures, which is a detailed interpretation for summarizing and an abridged one for IR, has been developed to mediate between the users' and the system perspective. Within these interpretations, the form itself is represented by constants, the user query provides variables.

Chu et al. [3] developed a scenario-based digital medical library which consists of scenario-based proxies, context-sensitive navigation and matching, content correlation of documents, and user models. The use of scenario based proxies here refers to relevant information can be obtained by direct access and similar-to search or content correlation links of the information sources. By using scenarios, this research aims at providing more focused searching thus to be more specific to the patient's medical condition.

Liu et al. [4,5] proposed a knowledge-based query expansion method that exploits the UMLS knowledge source to append the original query with additional terms that are specifically relevant to the query's scenario. Here, scenario-specific queries represent a special type of queries that frequently appear in medical free-text retrieval. That is, a scenario consists of several existing queries. This paper only used a knowledge-based query expansion method to improve the retrieval performance for such kind of queries.

Except for using scenario in retrieving medical text, Strasunskas and Tomassen [6] proposed a scenario-driven information retrieval approach to complement rule-based monitor of subsea production, which could be seen as a kind of view-based search. Because not all possible cases can be encoded in rules beforehand and precision of retrieving information is very important, the information retrieval should be adjusted to the scenario. Strasunskas and Tomassen first described the information and knowledge resources that enable users to formulate task-specific queries and then presented how system automatically formulates a query that is sent to a vector-space model information retrieval engine.

In Shen et al. [7], a scenario-oriented recommendation system was developed to help people to determine the ideal productions even when users don't necessarily know exactly what product characteristics they are looking for. Shen et al. used a common-sense reasoning system to map between the goals stated by the user, and possible characteristics of the product that might be relevant. Scenario-oriented recommendation breaks down boundaries between products' categories, finds the first example for existing techniques, and helps promote the independent brands.

Overall, a very few reviewed search methods provide the ability to review the changing history of specific information units. More importantly, the reviewed approaches don't provide the support for end users to dynamically construct the complete information scenario formed by the effects of the data/information changes and to record & replay the information scenario as a whole. Experienced from our earlier work [8,9,10,11,12,13,14] suggests that presentation, analysis and review of information can be significantly simplified and enhanced through a new paradigm that combines information visualization with allowing information to be managed, played and replayed in a dynamic and interactive manner on the basis of a formally constructed and meaningful domain information scenario.

3 An Overview of Scenario-Oriented Method

In this research, a scenario is defined as *a structure description of multi-dimensional information clusters to express the sequence and/or linkage of real practices computerised in an information system.*

The basic idea behind the *scenario* is that, in order to trace the changing history of certain information unit, the specific information unit should be put into *context* to reveal how it evolved and how it interacted with other information units in an application domain. Therefore, the default semantics of scenario, which is used to represent the real medical activity, is interpreted as "*who did what operated by whom in what time and where, under what condition and for what reason*". Scenario can be either *simple* or *complex*. A simple scenario just describes one specific medical activity, such as, *patient_take_urine_test*. But it can't give global descriptions of an application domain. Thus, a complex scenario is developed to represent a complex activity of a certain application domain. For example, a scenario about a patient therapy history is a complex scenario, which consists of several test-taking events or other treatment events. A complex scenario is composed of different existing scenarios (simple or complex) in order to show the dependencies and interactions in the application domain.

In order to facilitate the process of replaying healthcare information by following the scenario-oriented method, a scenario model together with a specification language is developed. This scenario model is mainly used to specify what to be recorded and how they are linked – this will be helpful for the future play-back and query as the structural link at the conceptual level of the information unit are specified (so a querying path at conceptual level can be decided at this level without concerning to logical or lower levels).

A scenario language is also investigated and developed to support the scenario-oriented method. The scenario language consists of two main components: a specification component and a query component. The specification component provides the ability to specify scenarios by following the structure of scenario. The query component provides a scenario-oriented query language that is used to manipulate and query scenario; it also supports the concept of replaying information scenario, by using a replay scenario statement in high-level and combing information visualization techniques, to help users to understand the domain information. The scenario language is a high-level, declarative and XML-based language. The grammar syntax is defined using the XML schema, and the scenario specifications are represented as an XML document.

4 Applying the Scenario-Oriented Method to Healthcare Information: A Case Study

4.1 Description of the Microalbuminuria Protocol

The MAP, as shown in Figure 1, is a clinical protocol for the diagnosis and treatment of microalbuminuria in diabetes patient [9].

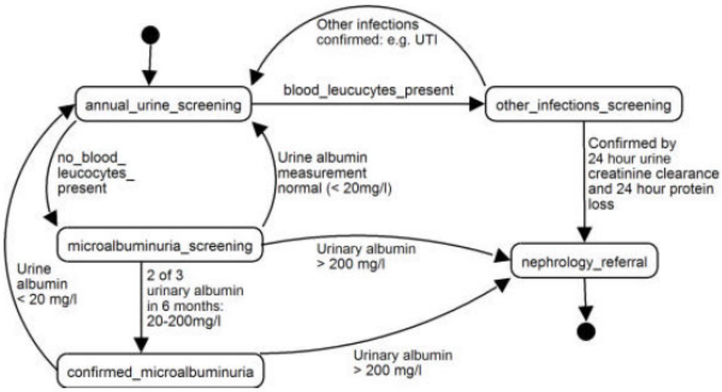

Fig. 1. State Chart for the Microalbuminuria Protocol

In the MAP case, there are several medical activities executed during disease management. These activities can be classified into: when patients are in the state of annual_urine_screening, they take Dip-Stick Urine (DSU) test; when patients are in the state of other_infections_screening, they take Urine Track Infection (UTI); patients take 24 Hour Creatine Clearance and Protein Loss (24CRCL_PL) test based on the result of UTI; when patients are in the state of microalbuminuria screening, they take Albumin Creatine Ratio (ACR) test and Serum Creatine Ratio (SCR) test both; when patients are in the state of confirmed microalbuminuria, three activities Optimizing Glycaemic Control, checking Blood Pressure (BP) and prescribing Angiotsin Converting Enzyme Inhibitors (ACE) will be executed for patients; when patients are in the state of Nephrology Referral (NPH), they will get a Referral Note. The medical activity "patient take urine test" will be employed as a main example to explicitly illustrate how to use the scenario-oriented method for recording & playing back healthcare information. The more details of MAP can be found in [9] and [11].

4.2 Applying the Scenario-Oriented Method to Healthcare Information

Figure 2 shows the overall strategy of the scenario-oriented method for recording & playing-back healthcare information. Our method starts with requirement specification by using the structural model to express the components, attributes, and inter-relationships within the system. The structural model is a 'network model', which could be seen as layered and connected ER model.

Query Vocabulary. The *query* vocabulary will classify the identifiers (entities/objects/relationships) referred in the information system into six categories so as to reflect different angles/aspects of information scenarios. Such as, for a treatment activity that patients take urine test, the entity *patient* and entity *doctor* will be classified into *WhoList* to represent the people who execute the activity. The relationships *take* and *executed_by* will be classified into *ActionList* to represent the action operated by people. *WhatList* includes entity *urine test*. Attribute *examine.begine_time* and *examine.end_time* will be classified into *WhenList*. Attribute *examine.location* is in *WhereList*. The constraint *dsu_constraint* (only the status of patient is annual_urine_screening, patient could take dip-stick urine test) and rule *r_dsu* (for the end of year, patient takes the urine test) are both classified into *RuleList*. Furthermore, each identifier classified into query vocabularies will be specified in the form of database schema so as to provide a way to store the information about these identifiers into data repositories.

Scenario Space. The *scenario space* defines/includes Pre-defined *scenarios* of concern, of which certain aspects will be recorded, and can be played-back during the running-time of the information system. It is constructed based on the structural model and query vocabulary by following the formal structure of scenario. The scenario space for the *patient_take_urine_test* is presents in Figure 3. This is a personalized diagram derived from the structural model for MAP, which is only respect to the real medical activity about "patients take the urine test" in healthcare domain. And also, the elements *operated_by*, *whom*, *constraint* and *cause* are added into this scenario space to capture the full semantics of a scenario from different angles. Thus, the semantics represented by this scenario can be interpreted as "*patient take urine test executed by doctor, in examine.location, from examine.begin_time to examine.end_time, in the condition of the dsu_constraint and caused by r_dsu*". The tag labelled for each block in scenario space, such as *who* in *patient* block, has two functionalities. One is to reveal this identifier selected from which vocabularies. The other semantics of tag is that, when labelling the tag at the upper left corner of block, the history information about this identifier will be recorded for later playing-back.

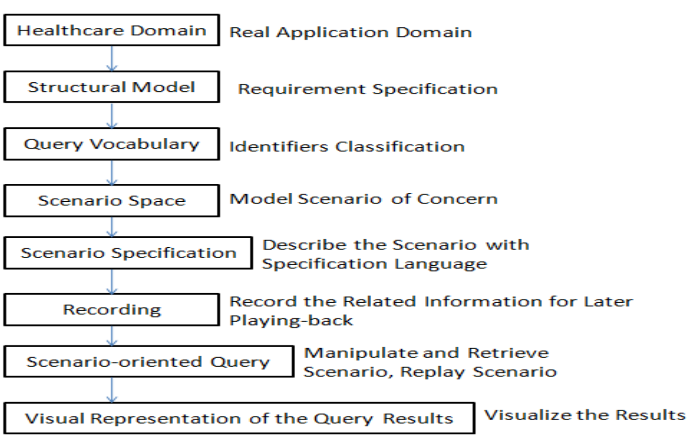

Fig. 2. The Flow Chat for Scenario-oriented Method

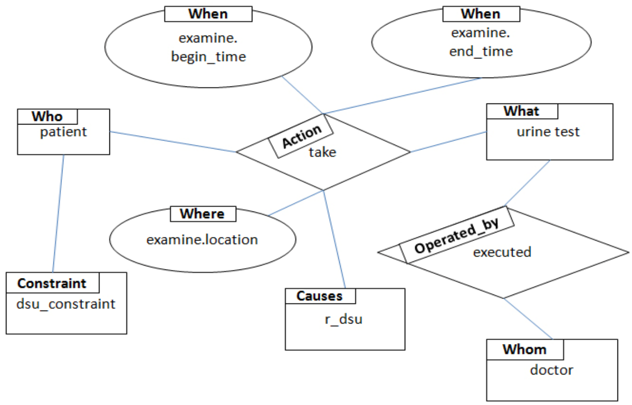

Fig. 3. Scenario Space for Patient Take Urine Test

Scenario Specification Language. In this research, scenario can be represented either by a graphical modelling (scenario space) or by a *scenario specification* language. Figure 4 shows the description of scenario "patient take urine test" that users are interested in. The *Header* element provides the descriptive information regarding a simple scenario. The *Id* element is used to provide unique identification for this scenario. The *Author* element presents the people who designed this simple scenario. The *Access_Right* element represents the authority of this scenario. Each simple scenario has a life-cycle in the system. Therefore, the *Design_Time* is used to describe the beginning time of simple scenario and *Terminate_Time* represents the end time of this scenario. The *Cause* element is used to specify the rule that starts the execution of process. It interprets "for what reasons" in the semantics of scenario. The *Constraint* element specifies some rules to standardize a process. It interprets "under what conditions" in the semantics of scenario. The *Process* element is the main component of simple scenario. It interprets "who did what by whom, in what time and where" in healthcare domain. Since the syntax of scenario specification language is defined by XML Schema, the description of scenario could be expressive to specify the user-centred domain knowledge not by programming language, and these information clusters could be managed by computerized approach.

Recording. While specifying the scenario *patient_take_urine_test* and labelling the tag for its identifiers, the related information will be specified to be recorded. The recording mechanism divides these information clusters into two parts and employs different methods to store them separately. The *domain information recording* will record the information sources of identifiers referred in this scenario. When an identifier is tagged in the scenario space, such as tag *whom* for *doctor*, the system begins to record information about this identifier. Each identifier (e.g. doctor) will have many instances (e.g. Jan, Patrick) with real data values in data repository. And for each instance, its whole changing history will also be recorded by default. The *scenario recording* is used to record the relationships among identifiers that constitute the scenario *patient_take_urine_test*. This scenario specification (shown in Figure 4) will generate many instances (e.g. Peter take his urine test) obtained by a XML document.

```
<SScenario name="patient take urine test">

    <Header>
        <ID>ss00001</ID>
        <Designer>Yi Ding</Designer>
        <Design_time>2010-11-3</Design_time>
        <Terminate_time>Now</Terminate_time>
        <Access_Right>Write</Access_Right>
    </Header>

    <Causes>
        <Cause ref = “r_dsu”/>
    </Causes>

    <Constraints>
        <Constraint ref = “dsu_constraint”/>
    </Constraints>

    <Process>
        <Who ref = “Patient”/>
        <Action ref = “take”/>
        <What ref = “urine test”/>
        <Operated_by ref = “executed”/>
        <Whom ref = “doctor”/>
        <When>
            <From ref = “examine.begin_time”/>
            <To ref = “examine.end_time/>
        </When>
        <Where ref = “examine.location”/>
    </Process>
</SScenario>
```

Fig. 4. The Specification for Scenario *Patient_Take_Urine_Test*

The instance of identifier referred in the scenario instance is specified by its ID in the XML document. When retrieving this scenario, the system will access real values of the object instance pointed by its ID from database directly and represent them under the structure specified by the scenario.

Scenario-oriented Query. After recording the needed information, how to formulate queries in the terms of path through scenario space to trace the changing history of specific information unit is the next phase of our method. The comprehensive query clause REPLAY SCENARIO statement is adopted here as the main tool to formulate the specific history queries. Based on the scenario space shown in Figure 3, several history queries could be expressed from different angles in high levels. These questions include: “what…?”; “where…?”; “when…?”; “who…?”; “how…?”; “why…?” or the whole evolution process. Some examples are presented as following:

Task: who did take the urine test, in what time, where and executed by whom?
Command: **REPLAY Scenario[name=“patient_take_urine_test”]**
FROM Who, When, Where, Whom;

Task: When did Peter take what test, the reason and what’s the test result?
Command: **REPLAY Scenario[name = “patient_take_urine_test”]**
FROM What, Cause
WHERE Who[name = “Peter”];

In MAP case, one of the most complex question is that “how to review a patient’s therapy history of MAP”. Assume that we have specified the needed simple scenario, such as patient take urine test, moreover, the complex scenario represents the therapy history is also constructed. Thus, the command for querying this question can be seen as follows:

Task: Review the Peter’s therapy history of MAP;
Command: **REPLAY Scenario[name=“patient’s_therapy_history_of_MAP”]**
WHERE Who[name=“Peter”];

Some expected results are presented as follows:

Peter takes DSU (result is negative) executed *by* Jan, *in* Lab 201 *from* 2010-12-1 10:00 *to* 2010-12-1 10:34, *for the reason:* the end of 2010, Peter take DSU test (rule r_dsu);

Peter takes ACR (result is 60mg/l) executed *by* Jan, *in* Lab 202 *at* 2010-12-2 11:00, *under conditions:* Peter.state = micro-albuminuria-screening, *for the reason*: if the result of DSU is negative, take ACR test;

Peter get referral note (nephrology) created *by* Kevin, *in* Lab 101 *at* 2011-6-4 12:05, *under conditions:* Peter.state = NPH, *for the reason*: CMA6 (if ACR>200mg/l, place patient into NPH state) and NPH1 (if the state of patient is NPH, then create referral note for patient).

Combining with query-response approach and information visualisation technology, and also considering the content comprehension to human sense, we will list our results as writing a set of sentences in the form of "who did what by whom, in where and when, under what conditions and for what reasons".

5 An Architecture to Implement the Scenario-Oriented Method

Figure 5 shows a proposed implementation architecture, which demonstrates the applicability of the method, to support the idea of playing-back healthcare information within the context of scenario. There are six main components in the architecture: 1) an user interface; 2) a scenario modelling component; 3) a recording component; 4) a real-time information system; 5) a scenario language component; 6) a replaying component.

The *real-time information system* component is mainly used to execute the real medical activities in a computerized way. The *User Interface* component provides the functionalities for end users to manage the real-time information system. It also enables users to construct and update the scenario model representing their specific history queries on healthcare information. In addition, the *User Interface* provides the functionalities to manage the life-cycle of scenario as well as replay the changing history of focused information units and visualize the results to make it human understandable (an example of visualizing the replaying history information can be found in [14]). The *Scenario Modelling* provides a recording mechanism to specify what kind of information needed to be recorded at conceptual level. In addition to this, it also enables end users to construct their specific *scenario* by integrating the different information and knowledge elements together based on certain logical relationships. The *Recording* component provides the ability to implement the recording mechanism to store the information clusters specified to be recorded into data repository by using DBMS instance. Domain information recording and scenario recording are employed to record the needed information from two directions. In order to manage the scenario in a computerized way, the *Scenario Language* component is mainly used to support the scenario specification, manipulation, and querying. Furthermore, comparing to the static text information provided by using the SELECT statement, the *Replay* component has the ability to translate the concerned scenario streams into a visual representation so as to take advantage of the human eye's broad bandwidth pathway into the mind to allow users to see, explore, and understand the healthcare information.

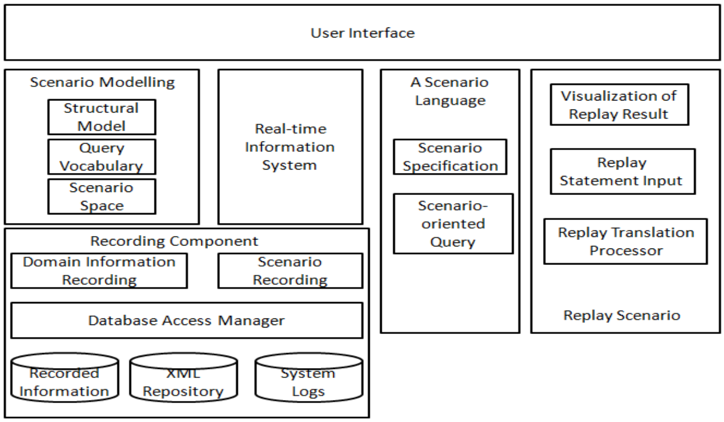

Fig. 5. An Implementation Architecture

6 Conclusion

Computerizing best practice in the form of healthcare information not only involves the domain knowledge specification and execution, but also involves the ability of replaying to enhance the reporting and decision-support capabilities in the organization. This paper proposes a *scenario-oriented method*, for supporting the idea of playing-back healthcare information. The healthcare domain is of particular benefit to the employing of scenario-oriented method. As this method is for supporting the playing-back of general *complex information*, it would also be of help to other application domains, such as aviation, personal information management, etc.

This work presented here is part of on-going research. As to the next step of this research, a prototype system with more comprehensive case study will be implemented to demonstrate the applicability of the scenario-oriented method and the implementation architecture.

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A Patient Referral and Counter-Referral Management System for Hospitals

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Abstract. The increasing demand for superior medical attention, in addition to the low amount of resources in many of our country's health care institutions, has made patient referral and counter-referral an important administrative process that begins with a referral from a lower capacity institution to one with more complex assistance and diagnoses, and ends with a counter-referral to the original institution, with a specific diagnosis, information on the services administered and indications for further assistance. Poor communication among hospital professionals can sometimes result in unnecessary costly referrals and late transfers that can prove deadly. This article presents an informatic system developed with Free Open Source Software technology that encourages an efficient usage of Dr. Noel H. Sbarra Specialized Hospital services, to improve the interaction among professionals of the health care network, in order to increase the capacity of the primary health care center and, thus, avoid the unnecessary transfer of younger patients.

Keywords: Free Open Source Software (FOSS), J2EE, referral and counter-referral, medical records.

1 Introduction

In Argentina, certain public hospitals, both provincial and national, have a staff of reputable specialists and medium-to-high complexity technology that distinguishes them from the rest of the health institutions. It is important to clarify that our health system has been designed in levels of increasing complexity in order to optimize the use of resources. That is, as a way of preventing diseases and attending to the prevalence of some pathologies, there is a greater supply of primary care at the base of the pyramid, and, progressing upward in technological sophistication and professional expertise, the offer is reduced, and therefore concentrated in only a few referral centers such as those mentioned before. The absence of certain technical

M.M. Cruz-Cunha et al. (Eds.): CENTERIS 2011, Part III, CCIS 221, pp. 185–193, 2011.

and human resources in small towns and provinces other than Buenos Aires is thus explained by the pyramidal logic used for our health system [1].

For this reason, these centers receive consultations and patient referrals which mainly come from polyvalent hospitals, ambulatory care centers and educational and social development institutions, where lack of resources and specialists can sometimes make it difficult for patients to obtain accurate diagnoses and adequate treatment. Statistics also show that the number of patients treated at Sbarra Specialized Hospital has increased in recent years: in 2008, 409,677 patients were treated at the Hospital, whereas the figure rose to 433,910 in 2009, and reached 493,074 in 2010 [2].

The human and material resources used to respond to the referrals and transfers mentioned above could be employed more efficiently through informatic systems, which are limited at the moment. These systems would enable web interaction to obtain an efficient professional assessment and avoid unjustified transfers, reducing time and costs. For this reason, last year and after many meetings with medical professionals from the Neurology area of the Sbarra Specialized Hospital [3], we began to implement a system for this institution together with students from the Workshop on Software Production Technologies [4].

This development basically pursues the optimization of the resources in the crowded pediatric hospital, in order to make it easier for the professionals in the primary care centers to solve problems on site, aiming at improving the service quality in all care levels.

This system provides, among other things, support and infrastructure for the process known as patient referral and counter-referral. This process, as its name indicates, consists of an initial stage, the referral of patients, during which a child is transferred from a smaller institution to one of greater complexity for adequate care, where they remain until discharged or transferred again to the original institution to seek the recommended treatment. This stage is known as counter-referral. The system facilitates the process, but also encourages early distance communication between the professionals involved. This web application is the first approach to the concept of bringing medicine to the point of primary care [5], i.e., bringing the most suitable tools to the doctors in the point of primary care to give them advice about therapeutic methods, diagnoses, protocols, experiences and to help avoid unnecessary referrals.

2 Setting

The Sbarra Specialized Hospital is one of the most qualified health centers for children and adolescents in La Plata. It receives patients from different parts of the province of Buenos Aires, the most populated province in Argentina. Patients from far away places -and their families- travel many kilometers to reach the institution and gain access to specialized attention and complex equipment, as the hospitals and health care centers they are transferred from are normally general-purpose facilities with very few pediatric specialists.

On the other hand, unnecessary and late patient transfers are not infrequent and produce undesirable consequences.

A system that facilitates interaction among professionals from the Sbarra Specialized Hospital (internal doctors) and professionals from local and zonal hospitals (external doctors) would eliminate the frustration these consequences bring. This interaction would facilitate: (i) consultations between internal professionals—doctors, psychologists, speech therapists, and others—and external professionals in relation to therapeutic methods, diagnoses, protocols, etc.; (ii) avoiding transfers, by means of adequate information (iii) enabling/speeding urgent transfers. However, there are always extemporaneous patient transfers with irreversible clinical situations, and, in these cases, frustration is inescapable.

An informatic system would enable fluent communication among professionals. In consequence, external professionals would be able to consult internal specialists and receive advice on the treatments they can apply in the point of primary care before requesting patient transfer. From point of view of the patient, being surrounded by their family and friends favors progress; and from the point of view of the specialized hospital, *human resource management would improve*—meaning more availability for children who really need it. *Hospital resources would also improve,* meaning more availability of complex equipment for situations that require them.

The system would also mean the first significant step towards the generation of a case knowledge base. This could help, in the future, to solve similar cases, as well as to observe, with efficient, adequate and updated medical information, the evolution of different treatments. This case base could be used by external professionals for similar pathologies.

3 System Features

Access to the system requires a computer with Internet access, a web browser and an authorized account with access to one of the system user profiles. With these minimum requirements, it is easy for doctors to gain access to the system from the hospital, from their office or even from their home. Among future work planned for this year, we have considered making the system accessible through handheld devices and other mobile technologies, which would facilitate, for example, updating the medical history of a patient while at their bedside [6]. Below is a detail of the features associated with the three user profiles in the system.

3.1 Manager Profile

A manager is an informatics professional responsible for maintaining the system data, creating users, granting permissions and carrying out all the tasks related with the data and the correct functioning of the system.

Fig. 1. System tables management screen

Figure 1 shows the screen for the management of professionals. From this screen, managers can add, modify and delete professionals, as well as list them by any of the visible columns, and export them to OpenOffice spreadsheets or .pdf files for printing. These management features are the same for all of these tables.

3.2 External Doctor Profile

An **external doctor** is a professional who is responsible for one of the entities external to the Sbarra Specialized Hospital. Basically, they can make distance consultations, make referrals to the specialized hospital and consult the health of the referred patients through the system.

Figure 2 shows the screen used to create a new distance consultation. This form enables a doctor to send studies and questions about a patient to another doctor or to hospital services. Consultations work similarly to internal mail systems. Users can specify the text of the message and select the addressee out of a list of the professionals and services of the Sbarra Specialized Hospital. This service allows for the attachment of files (x-rays, clinical examinations, clinical history, etc.) and the definition of keywords for future search.

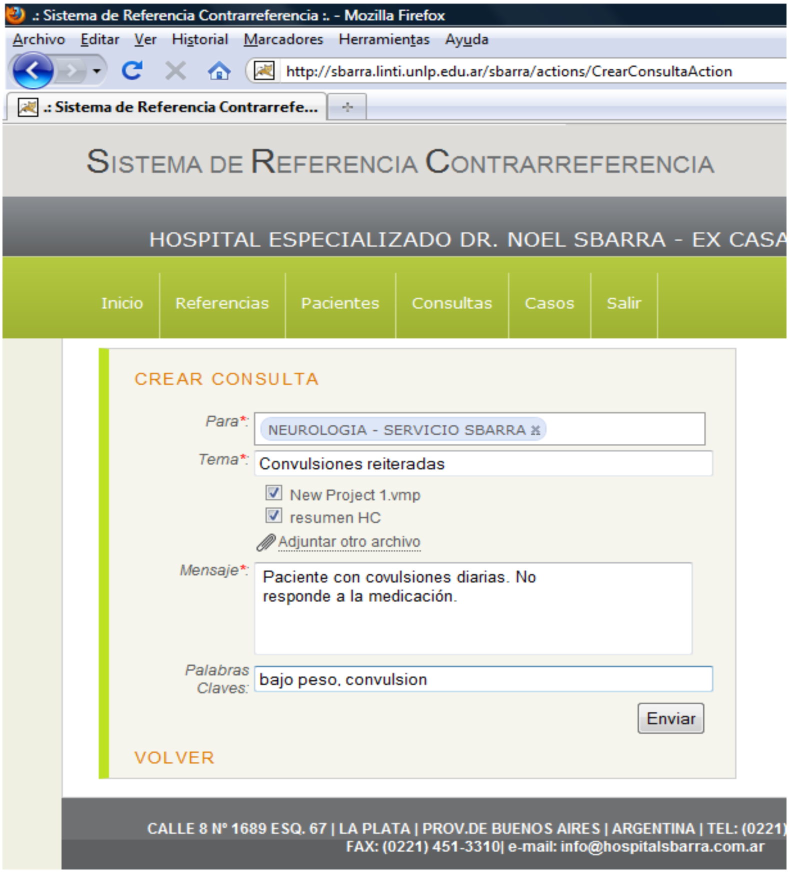

Fig. 2. Distance consultation form

3.3 Internal Doctor Profile

An **internal doctor** is a professional who works at the Sbarra Specialized Hospital, and is basically allowed to receive and answer consultations, generate counter-referral of patients in the Hospital, redirect the consultation to an internal service and follow the health of the counter-referred patients to evaluate their progress and eventually make suggestions to the head doctor.

When internal professionals access the system, new information is shown to them, including: (i) new consultations, (ii) unanswered referral requests, (iii) follow-ups scheduled for that day and (iv) appointments for patients in their practice. The system home has direct links to all of these news items. Figure 3 shows the homepage of a doctor, who has 4 new consultations, and on top of that image, the message inbox of the same doctor with the new messages.

Fig. 3. Home and message inbox displays

4 Applied Technologies

The *Workshop on Software Production Technologies* aims at introducing students into a context of realistic software production, using state-of-the-art technology in Java and free software. Over the course of the subject, students explore the various libraries that are part of the standard Java platform for distributed application development, known as Java EE or Java Platform, Enterprise Edition [7].

Java EE is a standard developed and maintained under the Java Community Process or JCP[1]. It includes several API specifications, such as Servlets, JavaServer Pages, Enterprise JavaBeans, Portlets and various web service technologies which are analyzed and used in practical applications in order for students to become familiar with the wide variety of Java technologies. This subject also teaches students to use free software tools such as Web containers, the Java EE container, database engines, development environments and frameworks for Java. In the next few paragraphs, we will synthesize the open technologies selected for the development of our Counter-Referral System, SRC:

- ***Java Servlet Technology and JavaServer Pages (JSP pages)*** are the server-side technologies that have dominated the server-side Java technology market; they have become the standard way to develop web applications [8].

[1] Software development community led by SUN. The URL with specifications is http://es.wikipedia.org/wiki/Java_Community_Process

- For data persistence, we used ***Java Persistence API or JPA***, the standard management interface for persistence and object/relational mapping of the Java Enterprise Edition 5.0 (JEE 5) platform. JPA is part of the EJB 3.0 specification [9],[10] and it is supported by most providers of Java EE containers.
- The ***Apache HTTP Server*** is a project of the Apache Software Foundation [11]. The goal of this project is to provide a secure, efficient and extensible server that provides HTTP services in sync with the current HTTP standards. Apache is an open-source HTTP Server and has been the most popular web server on the Internet since April 1996.
- Tomcat is a Java Servlet and JSP container and web server from the Jakarta project of the Apache Software Foundation [12]. Currently, we are using ***Tomcat 5.5*** which is the implementation for the Servlet 2.4 and JSP 2.0 specifications.
- ***Eclipse*** is an open source integrated development environment or IDE [13]. A Java development often requires access to tools that support HTML, XML, Javascript, SQL, and an installation of Eclipse may be enhanced by plugins to support all these technologies.
- To synchronize the software versions developed by different programmers, we used the version control system ***Subversion or SVN*** [14]. This tool is an evolution of the first concurrent version manager -CVS or Concurrent Versions System with the following optimizations: efficient use of bandwidth at the time of the information transfers over the network, improved creation of branches and labels, optimized management of binary files, etc.
- ***Mantis*** is a free web-based bugtracking system [15] that provides traceability and resolution of bugs throughout the software development, thus contributing to improving software quality and collaboration of the various components of a project. They are necessary when working in teams with different functions and working in a distributed manner as in this project.
- For information storing, we decided to use ***MySQL*** [16], a data base engine that gained popularity in the open source community. This engine is available under both the GPL license and commercial ones. Also, the use of Java JPA technology allows for independence between the application and the database engine used for persistence, facilitating the migration to any other Relational Data Base Management System (RDBMS).
- Using a framework for developing a web application not only speeds up the development process but also promotes best practices for implementation. Considering the skills of the average student in our subject, we decided to teach ***Struts 2*** [17], [18], a framework for the development of web applications that implements the MVC (Model-View-Controller) design pattern and is also compatible with the Java EE platform that is seen throughout the course of the subject.

The Referral/Counter-Referral System (SRC) is a multitiers web application where all the technologies described above are applied. In the scheme of implementation shown in Figure 4, two modalities for the client layer are shown: one using desktop technologies and another using mobile technologies. In the middle layer, the front-end is a web server—Apache—to avoid most of the security problems, followed by a web container—Tomcat—to support the execution of Servlets and JSP Pages which also has a JPA engine to access the database engine using object/relational mapping.

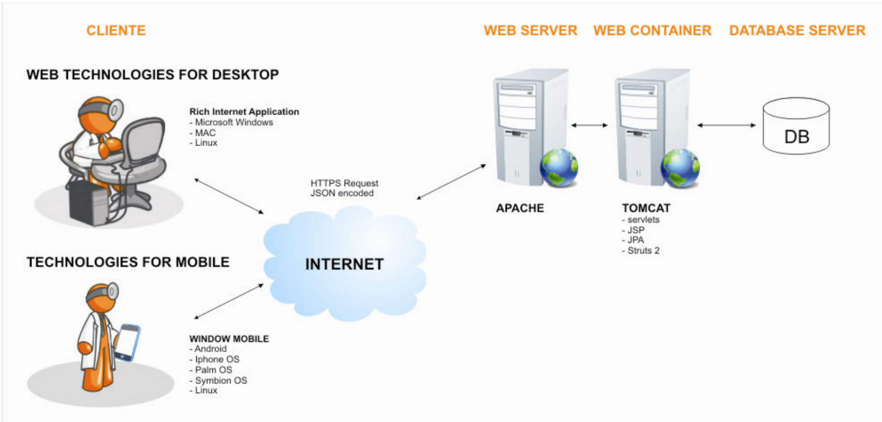

Fig. 4. Implementation outline

5 Current State and Expectations

At the beginning of this year, we were given space in the Sbarra Hospital monthly seminar, where the most difficult cases of each month are presented, to introduce the doctors in the different services of the Hospital to the new system. During the presentation, we simulated the referral and counter-referral process for a fictitious patient, showing the entire process, from the successive distance consultations to the follow-ups after the counter-referral.

During this presentation, the doctors were able to internalize the characteristics of the system and were able to ask questions related to information privacy and coordination with high-recording system in connection with outpatient follow-ups. The professionals behind this initiative hope that the implementation of this system and its increasing use will help strengthen the formation of health care networks. Currently, both students and teachers are training health care professionals in the use of the system.

6 Conclusions

In this article, we present the experience of a university extension activity for public hospitals. As a result of this, the Dr. Noel H. Sbarra Specialized Hospital and its contact network will have a modern, web-based system to manage the process of patient referral/counter-referral and distance consultation among doctors. The system, as already stated, uses free technologies, so that any medical professional with Internet access will have access to the service.

We observed that students were highly motivated with the development of a system that would later be used by a hospital in our city. In addition to the development of a system with social impact, the students were also able to experiment with open technologies and interact with real users of a system before their graduation.

Future work will mainly focus on improving the management and the security of the information in the medical records. We want to incorporate digital signature to carry out the provisions of the recent 26.529 Act [19] in relation to digitalized medical records, which seeks to ensure *"...the integrity, authenticity, age resistance, durability and recoverability of the data contained therein in a timely manner"* (Article 13 of the cited Act).

Another important aspect is the creation of a version for PDAs. The fast evolution of mobile devices and their recent availability in our country, added to the documented results—in developed and developing countries—that reveal that mobile technology improves efficiency in sanitary care [20], we have decided to extend the SRC by implementing a new system version for mobile phones, smart phones, PDAs, and other such devices. This alternative access will provide health professionals with more freedom to focus on their daily work, as they will have a portable, practical and agile tool that will enable access to precise information wherever they need it.

Finally, we hope the use of the SRC increases the amount of health care choices at the point of primary care and avoids unnecessary transfers of young patients.

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An Evaluation Methodology for Automatic Transcription System of Radiology Reports

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Abstract. This research combines knowledge from Computer Science and Health Science in order to propose an evaluation methodology for Automatic Transcription System of Radiology Reports. This methodology was designed based on Voice User interface requirements and specific requirements of automatic transcription systems of Radiology report. The same methodology was previously validated through some inspections and usability tests outside the hospital environment and, afterwards, it was used in two hospitals in São Paulo city. This approach aims to reduce costs of testing and available time by radiologists interviewed. Thus, the final product in this work consists of a set of criteria for evaluation of usability, comprising the name of the metric, evaluating method, steps to be followed and material to be used. By the use of this set, the evaluators can process the results of each requirement from the software.

Keywords: Usability Evaluation, Voice User Interface, Automatic Transcription System of Radiology Reports, Dictation System.

1 Introduction

Since the end users of computer systems began to be non professional people in computing, the Human Computer Interface (HCI) field has had a fundamental role in the success of computer products on market. Thus, in addition to meeting the desired features, an application should have intuitive and friendly interfaces to those users.

Emerging technologies have been integrated into interfaces available on the market: touch screen interfaces, three-dimensional navigation environment and voice use as a way to interact with the device are some examples.

Even though dialogue speech systems have appeared in the 1950's, during the onset of Artificial Intelligence research [1-3], a significant growth in the production of systems with users interface based on voice took place in the past decade, especially for commercial use via telephone, such as airplane ticket and hotel reservations, flight schedule queries and accessing bank accounts.

The research for usability evaluation of voice recognition systems is still quite new. The Methodology and suggested methods to evaluate Voice User Interfaces

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(VUIs) come from the present knowledge of User Interface (UI) evaluation, related to the work of some researchers that developed methods to investigate their specific projects, trying to generalize and to propose reference models for such applications. This is the case of PARADISE [4], EAGLES [5] and DISC [6].

If we analyze the use of voice recognition systems in the Health general purpose, such as in emergency, it is possible to see that they have not been effective due to the domain large vocabulary - it is known that the common vocabulary of the area has more than 100 thousand items. In other words, the information available inside Health field is extremely varied.

Thus, the voice recognition technology has been used for more specific purposes, such as automatic transcription system reports (ATSR) in Radiology field. It means that the vocabulary is considerably smaller, providing a higher accuracy in recognizing specific terms. Although usability is a quality attribute of software that aims to ensure that user requirements are attempted [7, 8], speech recognition systems in healthcare, there are mostly analyzed by methods complete, complex and well-established usability evaluation. The evaluators of such systems are still focused on evaluating only the accuracy or detecting mistakes in these systems [9- 12]. There are too many works in the literature that establishes the specific requirements of this area that must be met in order to make use speech recognition effectively and efficiently.

One of the main problems shown in the literature [9, 10, 13-15] is the delay in radiology reports due to the time spent from the moment of entry of recorded reports to its return in textual form for the radiologist to assess.

The automatic report transcription systems (that use VUI) have been thought of as a solution to decrease this time (Turn Around Time) and also to decrease the running costs of the radiology department. To verify the efficiency of the use of automatic report systems, not only the VUI general requirements must be evaluated but also the specific demands in the area, to see if the available commercial products have been used correctly by the users.

The objective of this article is, therefore, to organize concepts of voice recognition and also voice recognition systems evaluation aiming at proposing a useful set of methods that are feasible, practical and suitable. Thus, a specific methodology to evaluate this category of applications will be suggested.

This article is organized as follows: the second section covers the materials and methods used in research; section 3 presents results and discussions of methodology, and finally, the limitations and advantages of the proposed methodology are discussed and the future work is analyzed.

2 Materials and Methods

In order to make possible the development of a methodology to assess, simply and inexpensively the ATSRs in Radiology, it was necessary to establish three steps, namely: 1) identification of VUI generic requirements and ATSR specific requirements, 2) generation of a methodology for evaluating ATSR systems, and 3) application of the methodology. The following subsections detail these steps.

2.1 Identification of VUI Generic Requirements and ATSR Specific Requirements

Based on Nielsen evaluation [7] and [19], we propose that the following set of requirement should be formally assessed when evaluating VUI-based report transcription systems.

- **Accuracy:** It is one of the most important requirements, because wrong information can compromise report quality, alter a diagnosis and compromise a treatment.
- **Vocabulary Size:** vocabulary can neither be too larger-in order to lower the rate of word recognition nor too small for it does not consider the words in the application's dominion.
- **Specific Dictionary for Radiology Information System (RIS):** the system must consider words used daily in radiology reporting.
- **Noisy Interference:** depending on the area, hospitals can be very noisy, but this should not interfere on the efficiency of recognition.
- **Continuous Recognition:** the user must be able to dictate the report naturally, without having to worry about pauses between words, i.e., user must be able to speak in a natural and continuous way.
- **Integration with Hospital Systems:** Picture Archiving and Communication System (PACS), Hospital Information System (HIS) e RIS.
- **Help:** is linked to the ease with which users, especially beginners, will have to learn and access the help system to get to dictate a report efficiently.
- **Hand and Recover Error:** it is connected, for example, how the system works when it does not recognize a word dictated the user.
- **Adequacy of Feedback:** the system should not provide feedbacks that impair reasoning ability from user, but it is able to generate a report about errors dictated or unrecognized words.
- **Response Time of Feedback:** the transcripts must occur in real time without the delay that could interfere with cognitive load of the end user.
- **Adequacy of TAT:** time must be at least shorter than the human transcription systems.
- **Customer Satisfaction:** This requirement is linked to the pleasure of using a ATSR Radiology, measured by questionnaires.

Although it is known that most of these requirements must be thoroughly tested in order to verify their real value as the system itself - carried out by development enterprise - this paper is related to usability, which can be measured by a moderate amount of users and / or specialists even so as not to raise too much and to negate the cost evaluation.

2.2 Generation of a Methodology for Evaluating ATSR Systems

The proposed evaluation methodology must be able to:

- Use additional usability and inspection tests to provide a lower cost and shorter assessment time.

- Be applied to previously implemented systems.
- Act as a guide to evaluating the usability in this class of systems.
- Investigate the difficulties on evaluating specific requirements.
- Group the proposed requirements according to their characteristics.
- Propose metrics for evaluating each of those requirements.

To assess automatic report systems, the following classes (Table 1) were here defined in a modified way from what Möller [18] proposed in his work about general purpose voice recognition system evaluation.

Table 1. Classes defined in a modified way from what Möller [18]

Class	Requirements
Class 1 Achievement Requirements associated to the correct operation of the application without degrading its achievement	Accuracy, vocabulary size, specific dictionary for RIS, noisy environment, user's naturalness of speech (continuous recognition)
Class 2 Usability Efficiency and efficient requirements, decreasing the user's cognitive load	Minimization of memory overloads, adequate modality, time for the report to be ready
Class 3 Hardware and Integration	Requirements connected to physical achievement: Separateness between keyboard and dictation, use of proper architecture (client-server or browser-server), integration with existing systems, quality of audio system, and quality of database entries
Class 4 Human Factors	Requirements connected to the user's pleasure in using the system and the will to continue to use it
Class 5 Feedback	System's feedback time, system's visibility, feedback's adequacy, message exit quality
Class 6 Handling Error and Help	Requirements that are related to the capacity of the system in correcting not only errors found but also correcting a dictation, may it be in real or posterior time

The requirements were classified according to the level of assessment difficulty (Level 1 – low complexity, Level 2 – medium complexity and Level 3 - high complexity) as an example: accuracy; vocabulary size; noisy environment; continuous recognition fall in complexity Level 1, as in Table 2.

A method for analyzing each requirement was developed. A template was created for each requirement in order to facilitate the assessment, as illustrated in Table 3, for Customer Satisfaction.

Table 2. Complexity of the requirements

Complexity	Requirements
Low	Accuracy; vocabulary size; noisy environment; continuous recognition, time turn aroud.
Medium	Help system, Hand and Recover Error; quality of audio system, time turn aroud
High	System's feedback time, system's visibility, feedback's adequacy, customer's satisfaction

Table 3. A template for Customer Satisfaction

Customer Satisfaction	
Kind of Evaluation	Subjective
Evaluation Methods	Questionnaire
Importance	High
Difficulty in Evaluation	Level 3
Evidence to look for / Metrics to use	Ease of use, aggregated value, success of the task

2.3 Application of the Methodology

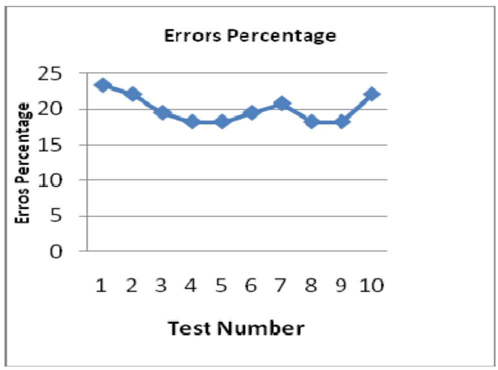
We apply the Usability Evaluation Methodology for the Automatic Transcription Systems Reports in Radiology in two ways:

- First, analyzing all possible requirements, with a stand-alone system (not inside a hospital). These requirements were analyzed using the techniques of satisfaction questionnaires, observation and inspection of usability in order to facilitate testing, saving time and costs, and disturb the least possible the radiologists.
- Second, analyzing the other requirements that could not be analyzed outside the production environment - i.e. inside hospital - with real users - Radiologists - using observation techniques and questionnaires of satisfaction. Then, we selected a user who uses the system more frequently.

Planning the Usability Inspection for Stand-alone System. Inspection of ATSR usability was performed according to the following steps:

- Conception of heuristics: for experts to check compliance with what the system was established.
- Choice of experts.
- Preparation of inspections: these inspections spend about 20 hours, one of the main reasons for not using the second professional for all inspections and also of not using more than two experts.
- Generation of lists: aims to generate the results and analysis of each particular test case for inspection, as shown in Table 4. At this stage, we observed the metrics listed in Section 2.1.

Table 4. Results of inspection

Metric	Hand and Recover Error
Evaluation Method	Inspection
Tester	1 expert
Materials	1 text with 77 words, with many words out of vocabulary specific to the area of radiology, a device SpeechMike.
Steps	Verify, by inspection, the system acts as if the user uses words that are not in the dictionary application.
Results	The text used in this report for the test has 77 words. The test was repeated 10 times (Graphic 1). This test spent about 17 minutes.
	Graphic 1. Error Percentage 
Analysis	In the case, the average error was 4.54%, with average deviation of 1,237%. However, this test was 20% with average deviation of 1.95%. This was expected, since the vocabulary for the system is specific to the area of Radiology.

Planning the Usability Tests for Stand-alone System. We used a methodology for preparation of tests adapted for Diah et al [16], Nielsen [7] and Mitchell [17], this plan consists of the following activities performed consecutively:

- Planning for usability testing: the tests were conducted inside a non-hospital environment, through non medical participants. We conducted two pilot tests to check possible inconsistencies. The main goal was to generate the results and analysis of each particular test case for the tests with end users.
- Preparing test materials: in addition to inspection of materials used, we also need: photography camera, pre-and post-test questionnaire and forms for user observation.
- Tasks establishment: The tasks aimed to validate the metrics (section 2.1).
- Participants' selection: we select six people (three men and three women) and two experts in inspection. Two criteria were determined: different tones of voice, both male and female, and people with different accents of the native people of São Paulo city.

- Conducting usability tests: the sessions were composed of four parts, with an average duration of 45 minutes.
- Analysis of usability problems, as shown in Table 4.

3 Results

We divided the discussions of usability tests results into two parts, one concerning the stand-alone system and another using a system deployed in a hospital in Sao Paulo city.

3.1 Stand-Alone System

Through all testing performed on this system, we can describe the following conclusions.

- The ATSR system was very efficient in relation to the speech recognition accuracy (93% on average), even including in the group people with pronounced accents.
- The voice accuracy reached 95%, even with minimal training of voice.
- The system is sensitive to changes in speed of speech.
- There is no significant difference in the rate of recognition without training and with training. Hence, the system could be used without being carried minimal voice training, with acceptable rates of voice recognition.
- The system delay to display the text on the window causes for people a feeling that the system was not working.
- Interference noise affects mainly the accuracy of speech recognition.
- The two devices used for the entry of the reports - HeadSet Philips SpeechMike and Philips - have proven successful. We had expectations of, according to information from the supplier,to have a big difference in sound quality; however, the recognition accuracy was better with the headset in low-noise interference. Among high noise interference, the device HeadSet was better SpeechMike. The significant cost difference between the two and ergonomic equipment must be taken as important aspect.
- Lack of visibility and adequacy of feedback were pointed by the users as uncomfortable.

3.2 System Used in a Hospital

We observed a end user and can to see:

- The Turn-Around time is about 5 minutes.
- The system is very sensible to environment noise.
- The radiologist needs a a high degree of concentration because it displays three screens simultaneously, as we can see in Figure 1.

Fig. 1. A radiologist using the system

3.3 Comparison

Through observation of the use of this system, we can conclude:

- The voice recognition rate was lower than shown by stand-alone system, maybe because its system version.
- When the typing service is used, the radiologist must review the medical image to confirm the report, already in use ATSR, it becomes unnecessary because the image is real time.
- Emergency Reports can be generated by the system more quickly (20 minutes x 5 minutes in average).

4 Conclusions

This article focuses on the evaluation of automatic transcription system for radiology reports. Various specific requirements in this class of systems that are not taken into consideration, either by the classic evaluation methodologies of usability or by the new VUI evaluation methods were identified. These requirements have been neglected when these applications are evaluated.

The methodology to provide these peculiar requirements based on usability inspection and usability tests was proposed, in order to assure a lower cost and a higher efficiency. It aimed at reducing costs with usability testing, to be known in the literature of HCI, this is a cost that may be impeding the evaluation of many systems.

Since the ATSR have been mooted as a solution to reduce the time for the report is ready, and also as a reduction of overall costs of the Department of Radiology, a methodology for evaluating these products is essential. The proposed methodology contributes to the choice of a system that faces the needs of the market relative to its end user. Thus, this methodology takes into consideration many aspects that go beyond the recognition rate of these systems, addressing issues such as size of vocabulary used, the environment used and user satisfaction.

Hence we tried to use, as much as possible, the inspection techniques that do not use these end users and significantly decrease the time and cost evaluations.

Also, for hospitals that did not require cumbersome and time available for its radiologists, we chose to use the inspection by experts in usability; also, volunteers were selected as users for usability testing, when the inspection was not most appropriate method. Only the observation of end users - radiologists - and filling, for them, a satisfaction questionnaire were the techniques used to analyze the usability when the need to be "in the field." This questionnaire took no more than 3 minutes from the time of the radiologist.

Thus, this work serves as a guide for IT field in hospitals and radiology clinics when evaluating whether to purchase systems for automatic transcription of reports, increasingly common in the domestic market. It can also be used to check when working with customizations such systems, the usability they want to reach and if it is currently in force.

It is desirable that the usability evaluation proposed by this methodology is carried out or led by experts in usability, it is necessary even for an expert, a sizable amount of hours primarily to the evaluation of inspection.

5 Future Work

We suggest as future work having more automation of tests, both with usability experts, and with volunteers and end users, which was not the initial focus of this work. Second, the use of intelligent agents that can capture the reports, change the dictation by synthesizing voice. This would reduce greatly the time of inspection evaluation, considered one of the key drawbacks to this methodology.

Third, we can indicate the use of a more extensive vocabulary of the reports in order to have a more accuracy measure of voice recognition.

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Projecto C: Surgical Cost-Effectiveness Analysis Database

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Abstract. In times of crisis like these, a cost-effectiveness analysis database for surgical procedures is the best tool to have. A number of clinical variables were defined to complement the cost-effectiveness analysis with one of first operation room expenditure's database implemented in a public hospital. This study is based on the same cornerstone of the ACS-NSQIP program. Some variables were collected automatically from the information systems available in the hospital, and the remaining are entered in a custom developed application be the surgeons. The indicators to provide are being defined with the surgeons and implemented in the form of dashboards. The result of this project will provide a tool for the hospital surgeons, manager and administrators to make better decisions.

Keywords: business intelligence, surgery, data mining, database, data-entry.

1 Introduction

There has never been a greater pressure for ensuring medical expenditure is controlled while waiting lists for surgery are reduced. These trends are shaping changes in hospital financing systems, hospital expenses with personnel and facilities and patient management. Tools that allow an informed interaction between parts involved - surgeons and managers - by integrating clinical performance information with that of expenditures, are either lacking or incomplete. There is also a need to collect, organize and analyse clinically relevant information for medical training, supporting routine care and conducting research.

Projecto C was conceived to try to meet some of these needs. The project consists on the development and implementation of a surgical database that could be a privileged meeting point between clinical and administrative data and interests in real time.

2 Background

The need for valid and up-to-date information to support medical practice definitely requires the combination of modern medicine and its production of high quality

M.M. Cruz-Cunha et al. (Eds.): CENTERIS 2011, Part III, CCIS 221, pp. 204–212, 2011.

medical literature, with the capability to disseminate and apply such information. Information technologies have a vital role in such translational science process [1].

Information services, supported by databases capable of capturing and storing information onto a structured framework, while presenting clinical data in a pleasant and user-friendly interface are indispensable tools for today's medical practice [2].

Hospital Professor Doutor Fernando Fonseca was pioneer in the creation of Enterprise wide Operation Room expenditures' database and entry system. Nonetheless a database that would integrate clinical variables was missing. Recording consumables, while useful for management and helpful for performance and cost monitoring is incomplete for cost-effectiveness calculations of surgical acts. Clinical data about pre-operative, peri-operative and post-operative variables need to be integrated to ensure cost-effectiveness is clinically meaningful to professionals and managers alike.

We, therefore, tried to capture the rigour of surgical quality programs like the ACS-NSQIP (American College of Surgeons National Surgical Quality Improvement Program), which is being used in USA since 1994, with impressive results in improvement of healthcare, granting undeniable prestige to the institutions in which it is implemented. The ACA-NSQIP is a validated a risk adjusted nationwide program, based on well-defined measures of effectiveness that assesses the overall quality of the surgical procedures [3]. It had its origin in a pilot project initiated in 1991 in the Veteran Affairs Hospitals, where was associated with a 31% reduction in 30 day mortality [4]. Recent data suggests the ACS NSQIP improved risk-adjusted mortality in 66% of the participating hospitals and morbidity in 82% [5].

This database will allow a better understanding of demographics, surgical risk factors, surgical procedures, inter-individual technical variations integrated with costs, not only associated with operation room consumptions, but also with patient morbidity and mortality.

3 Objectives

The aim was the development of a clinical and administrative database that allows monitoring of real time effectiveness indicators, clinical research information, management and cost-analysis reporting.

4 Methods

After a period of bibliographic research and software development, a pilot period is taking place with one of the hospitals general surgery department named 'Cirurgia C'.

We started with the collaboration of 10 surgeons, who contributed for application design as well as inserted in the database some of the patients submitted to surgery, regardless of surgery type or demographic characteristics.

Surgeons, in a custom-made software application, insert the preoperative demographic and clinical variables. The remaining data is automatically collected from other hospital applications, such as, laboratory information system, administrative and billing system and the operation room expenditure database.

4.1 Variables

The different variables are divided in three different groups; pre-operation, operation and post-operation. The pre-operation variables allow us to evaluate the surgical risk. Operation variables partly characterize resources and techniques involved in the procedure. Finally post-operation variables try to identify complications in a 30-day post-operative period. The number of variables per group is: 46 pre-operation, 15 operations and 27 post-operation.

The variables were defined from consultation of extensive literature support [6]-[26] and fertile on-going debate with surgeons involved.

4.2 Software Application

A software application was developed to support the clinical data entry for the variables that were not collected from other information systems in the hospital.

This application was developed in technologies such as Microsoft© Silverlight [27] and Microsoft© SQL Server [28]. The usage of a technology such as Silverlight provides a rapid application development (RAD) and ease deployment on the hospital, providing the surgeon access anywhere, where a computer is available.

The architecture of the application provides a simple and easy way to add, remove or modify the clinical variables. This dynamism in the variable definition was a requirement. This provides a faster decision-making on which variables are to be registered, and to ease the deployment in new wards, where there are new requirements.

This tool provides a list with all the hospital procedures, scheduled or already completed. When the surgeons select a surgery, a data entry form is shown where they can introduce the variables.

The clinical variable definition is achieved by a configuration database.

4.3 Telephone Questionnaire

Surgeons on the ward record some of the post-operation variables before or after discharge. The other variables, namely status at 30 days post-operation will be collected through a telephone questionnaire performed by a person designated by the hospital.

At the time of discharge all patients are informed about the telephone questionnaire. The telephone interviews are being held between the 30th-35th days post-surgery, regardless of the day of discharge. The hospital may select a subgroup of patient to be called in, for an appointment, depending on the complexity of the case.

The telephone questionnaire was built based on a literature review. [29][30]. The questionnaire comprehensibility was accessed firstly with pilot ward surgeons regarding the description of its contents as well as the overall construction, as well as with five patients who were randomly selected.

On the correlation of the questionnaire with the reality a sample of ten random patients was selected, and follow up appointments were held after one month.

The same telephone questionnaire was also carried by two different interviewers to 10 randomly selected patients within the same day and three days apart to evaluate its reproducibility.

4.4. Pilot Study

Given the innovative and complex nature of this project we started by a pilot study in which the database was placed to test at 'Cirurgia C' department. The timeline was not defined from the start as several software applications had to be perfected, new variables were to be added and others removed to achieve greater consensus amongst surgeons and enhance adherence and buy-in. During this period the hospital information system has evolved with several modifications that have forced us to adapt this software. Other surgery groups are being shown the project as well as inquired about variables and access.

We have now corrected several bugs and made considerable adjustments to variables but we cannot vouch for a perfect performance so the project remains in its pilot phase.

4.5 Information Dashboards and Data Integration

Information dashboards were developed using QlikTech© QlikView [31], a business intelligence tool that facilitates the development of dashboards.

The data integration is a challenge here, as we need to collect data from different systems with different technologies and structures. These systems are the laboratory information system (LIS), the operative room expenditure's, the administrative system responsible of admission, transfer and discharge (ADT), and the billing system.

The data integration was achieved using a common business intelligence process of ETL (Extract, Transfer and Load) to Staging database, so we can build our data model in QlikView according with the indicators discussed with the surgeons and management.

4.6 Cost-Analysis

Using multivariate regression we will be able to establish the cost of the surgery for each surgical team, according to the risk group and surgery type. This will also allow for comparisons inside those groups. Several algorithms for integrating this information are now in discussion.

5 Results

We are now ending the pilot phase with 62 patients included, and 64 surgical procedures, on the database. This custom designed, enterprise information data collection system is currently able to feed in real time, informative dashboards on QlikView. The surgeon are using it to produce admission, operative and discharge notes for the clinical file. Our design even allows for surgeons, to access in a simple manner their patients clinical information stored in the database from a remote access point outside the hospital in any Internet connected computer.

The algorithm to carry risk-adjusted, cost-analysis and quality improvement feedback was started. All the arrangements have been made to expand the usage of this database in another surgical and anaesthesiology department.

The software application developed is on Fig. 1and 2.

Fig. 1. Procedure list: This is where surgeons search the procedure they want to start the introduction of the variables that are need manual entry

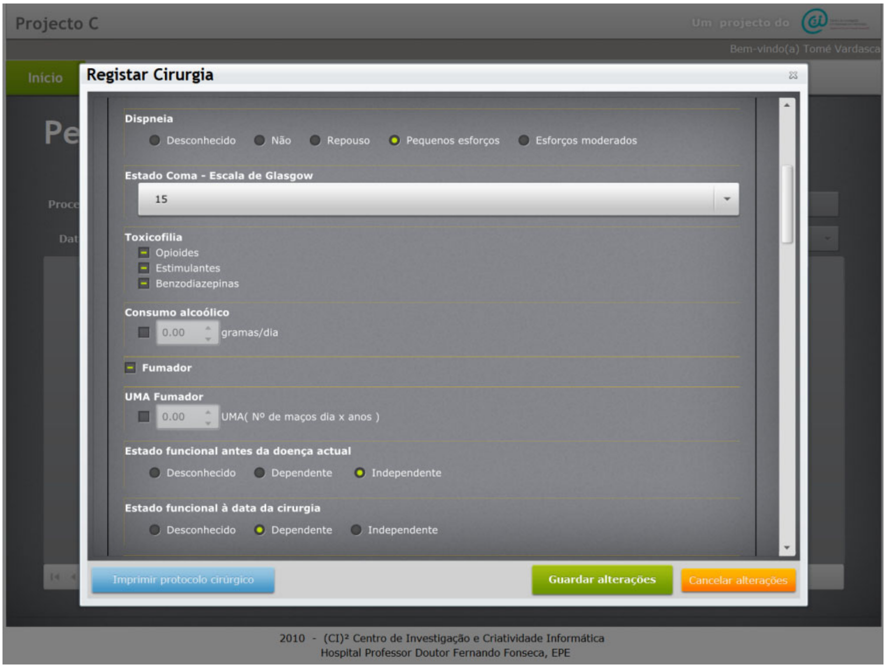

Fig. 2. Data entry form: This is the main interface where the surgeons register the variables that need manual entry

We created several dashboards with the help of the surgeons and the managers; an example is displayed in Fig. 3.

Fig. 3. A sample dashboard developed using QlikView©

6 Discussion

To our knowledge we are now running the first enterprise wide, validated, outcome-based, risk-adjusted, and peer-informed program for measurement and enhancement of surgical care quality. The number of patients in the database represent far less than the total number of surgical procedures that took place during the time period, which is expect during this pilot phase. Problems with the access to the application in the early days, the choice of variables and logistics to carry regular telephone questionnaires, all contributed to that.

We are now working on a standard operative procedure for the information to be inserted in a more reproducible way.

Increasingly the reduction in the amount of variables depending on manual insertion and efforts to embed the application into the hospital EHR will ease its use. Data-mining and reporting will help surgeons more and more in their clinical activities, surgery planning and learning processes, as well as to the administrative responsible controlling supply and demand as well as cost effectiveness of the consumables. Only further in time, all the benefits from this information system will start to pay off, as will some of the remaining reservations about the project disappear.

There is the necessity of more regular appointments with the surgery department and the management team. These appointments give a better understanding of what indicators need more work or what are unnecessary as the number of surgeries in the database is growing.

7 Conclusions

The data analysis allowed by this database will provide information to help surgeons, managers and hospital administration decision-making, in an unprecedented manner.

Projects like this help hospital do be more effective in a time of crisis, while caring for and improving patient safety and quality of care.

8 Future work

There is some interest at the hospital administration on the expansion of a system like this to all the surgery services, as it provides a better cost and quality control.

The surgeon teams are also interested on the data analysis for research purposes, using this project as a tool to scientific work.

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A Decision Support System for Surgery Theatre Scheduling Problems

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Abstract. From long to short term planning, the decision processes inherent to surgery theatre organization are often subject of empiricism. The current hospital information systems available on Portuguese public hospitals lack a decision support system component that could help achieve better planning solutions, thus better operational performance of the surgery theatre. Since the surgery theatre is the biggest hospital budget consumer, the use of surgery related resources and its intrinsic planning must be carefully studied. We developed a new decision support system for surgery planning conjointly with one of the largest hospitals in the north of Portugal. As for now, the goals of the DSS are to improve the planning process and increase policy compliance. We will enhance this framework by integrating data mining, optimization and simulation techniques in a way that enables a more accurate representation of the surgery theatre problems' stochastic nature, allowing the users to find enhanced planning alternatives.

Keywords: Surgery Theatre, Decision Support System, Scheduling.

1 Introduction

Demand for healthcare services is constantly rising and there is a great limitation to increase providers' capacity, hence, several paths for performance improvement arise. Besides, healthcare providers are constantly being pushed to improve the quality of its services, while thriving from government budget cuts. In this context, business process improvement and continuous improvement methodologies emerge as robust frameworks in the search for a more efficient utilization of the capacity available, enabling these organizations to cope with demand.

In this work, we present a decision support system (DSS) designed to help surgeons and hospital managers in the patient scheduling and resource allocation processes. The main focus is to respect patients' priorities and use critical resources more efficiently. The DSS was designed and implemented in close cooperation with a large Portuguese public hospital and our vision was to create a centralized platform built upon the pillars of communication, coordination and performance achievement.

M.M. Cruz-Cunha et al. (Eds.): CENTERIS 2011, Part III, CCIS 221, pp. 213–222, 2011.

The surgery theatre alone is considered to be the biggest hospital budget consumer and its performance has severe impact on societies [1]. A recent study [2], recognized Portuguese health care services as number 21 among 33 European countries, mainly due to its long waiting times for treatment. In fact, 2009 ended with about 165.000 patients still waiting for surgery, of which, almost 10% had already been on the list for more than 12 months [3], the median waiting time corresponded to 3.4 months. This scenario worsens if we acknowledge that when a public hospital exceeds 75% of the maximum allowable time to guarantee the surgery for a given patient, a voucher is issued to the patient that he can use in any private unit.

Despite the efforts that are being made to tackle the problem of long waiting lists, we find that the current hospital information systems have limited capabilities to create optimal surgery schedules or even to measure their quality. Decision making processes within the surgery theatre are often empiric and the available information systems lack this decision support component. We witnessed surgeons using different methods, such as paper based maps, spreadsheets and online calendars, to devise their surgery schedule plans, reducing the level of centralization to insignificant levels.

In our research we found that on the public hospital system, several applications exist and the level of integration is not sufficient to promote good practices. As we will describe ahead, there are three decision levels in surgery theatre planning (strategic, tactical and operational) which can be improved to increase surgery throughput and overall hospital performance.

We developed a new DSS which aims to support decision agents achieving better solutions when planning their surgery service or when allocating critical resources to the surgery theatre. The DSS was designed to improve personal efficiency, by improving the interaction of the agent with the system throughout the decision making process, thus speeding up its practice. Ergonomics play an important role when designing a user interface, improvements can be noticeable when accounting the number of mistakes avoided and it also gains importance when the learning curve is smoother, reducing the early resistance to adopt applications.

In the future we expect to develop an intelligent component to couple into the DSS and improve the decision support processes, such as patient scheduling. This intelligent component will be based on optimization, simulation and data mining techniques, allowing the optimal scheduling, simulation of new scenarios and revealing better ways to conduct the current planning tasks.

This paper is structured as follows. Section 2 introduces relevant concepts and problems found on the literature. The DSS development approach is described in Section 3, where the methodology and the resulting system's architecture are defined. On Section 4 we detail the features of our system and frame it on a small case study. Future works and final remarks will be presented on Section 5.

2 Literature Review

Throughout this literature review, we will focus mainly on the current situation of the national health information systems and surgery theatre planning problems. Although this paper presents a new DSS, we briefly introduce the concept and its application at the clinical level.

2.1 Portuguese Scenario

Although the overall Portuguese health care system was underrated [2], it ranked high on the field of e-health, mostly due to the early, but still in progress, adoption of the electronic health record. Paradoxically, most information systems found inside hospitals are outdated at the technological and functional levels [4].

Applications used in the majority national public health system needs to be updated, as shifting to a more electronic oriented system demands new features and developments [4]. The sustainability of the existing structures is also questioned, due to their high costs of maintenance and the need to guarantee system's interoperability, so that development is open to third parties and innovation is encouraged.

The main application used in the daily medical practice activity, Sistema de Apoio ao Médico (SAM), is outdated and has seen a decline on its utilization among Portuguese hospitals [2]. Alongside, systems connected to this network use different architectures, most of them also obsolete by now. Regarding the surgery planning activity, the SAM system is limited to the formal scheduling of patients and the planning phase is performed on an informal and decentralized environment (e.g.: paper based agendas).

2.2 Surgery Theatre Planning

Surgery theatre planning is today a far more complicated problem than it has ever been in the past. On one hand, patients demand higher standards of comfort and service and on the other hand, there is a greater desire for efficiency and economy.

Over the past, the surgery theatre has become a much discussed topic in the literature, where many problems and different solutions arise. Typically, the surgery theatre planning is split into three hierarchical decision levels (i.e., strategic, tactical and operational) [1, 5] and within those, several problems come up.

On the strategic level, research has been focused on defining each diagnose related group yearly capacity (case-mix planning), finding the ideal number of beds in a ward, facilities layout or process modeling [6].

The tactical level, which ranges from medium to long term, assures the allocation of surgery theatre time (master surgery schedule) [7] and it is critical to hospital's performance. This particular problem has to take in consideration not only financial criteria but also patient flow target measures.

Finally, problems of scheduling patients to surgery [8] or staff allocation are undertaken for operational short term planning. One can find an exhaustive coverage of this subset of problems in [1], which exposes the vast amount of work that has been done on this field.

2.3 Decision Support Systems

The DSS concept can be summarized as information systems that provide tools to support management activities, either in strategic planning, management and operational control.

DSSs help decision agents to analyze their options and find the best alternative among all. These systems have long proved to be effective when applied to various domains such as health [9], where two main applications should be distinguished: (i)

DSSs oriented to organization control, as we present in this paper, and (ii) clinical DSSs. The latter, concerns the operational level, where the goal is to mitigate harmful and expensive medical mistakes [10]. These are patient-oriented systems, where the main focus is to improve the clinical workflow to guarantee patient safety.

3 Decision Support System Design and Implementation Process

The DSS was developed using a user centered approach based on a traditional software engineering lifecycle model [11]: (i) identification of user needs and establishment of the requirements specification; (ii) initial design; (iii) prototype implementation and evaluation; (iv) final design; (v) implementation; (vi) validation and testing; (vii) deployment.

The first task of identifying user needs and establishment of the requirements specification was conducted through a series of workshops meant to characterize the surgery theatre scheduling process and assess where it could be improved. The workshops followed the Kaizen methodology [12] (continuous improvement) and were attended by surgeons, nurses and administrative staff. The workshops were not exclusively focused on the DSS development, but they were essential for understanding and characterizing business processes, as well as to identify the strengths and weakness of the current information systems.

As a result of these series of workshops, a requirements specification document and a set of low resolution prototypes were produced, which were then presented and validated by key users from the hospital staff. The low resolution prototypes were essential to validate the conceptual model inherent to the DSS and to incorporate the final users' feedback as early as possible on the project life cycle.

The first release of the system was initially deployed in two surgical specialties of the hospital as a pilot run and is now on the edge to be applied and used by the entire surgery theatre.

3.1 Architecture

The DSS was designed to be integrated with Hospital Information Systems (HIS) mainly by means of web services, in order to maintain a certain degree of independence from the underlying HIS. In the hospital that served as a case study, there is a third party integration agent named AIDA [13], whose main role is to communicate with heterogeneous systems, acting as the HIS communication layer.

In order to deploy the DSS to hospitals in the absence of a communication layer, specific integration components must be designed, with respect to public hospitals in Portugal, there is an ongoing project to add interoperability features into the actual systems [14]. When those features become available, integration will become standard and the DSS will become a natural extension of the most used HIS in Portugal [4].

Our DSS is a web based system, reducing the overhead of installing and maintaining the application on every computer, which is particularly challenging on a large scale organization. Its architecture was designed on principles of performance, reliability, maintainability and interoperability. To achieve those goals, an enterprise oriented architecture was adopted, dividing the software development in four layers: (i) data access layer; (ii) business logic layer; (iii) web/service layer; (iv) presentation layer.

In terms of physical infrastructures, in order to attain synchronism between the DSS and the HIS tiers, there are three main tasks to be taken to complete the update process (see Fig.1). First, an update service invokes a web service in the communication tier AIDA, requesting it to synchronize the data warehouse with the most recent data from the HIS. Then, the update service queries the shared database and updates the DSS database. The image below depicts the main components in the described process and on a higher level the interaction between them.

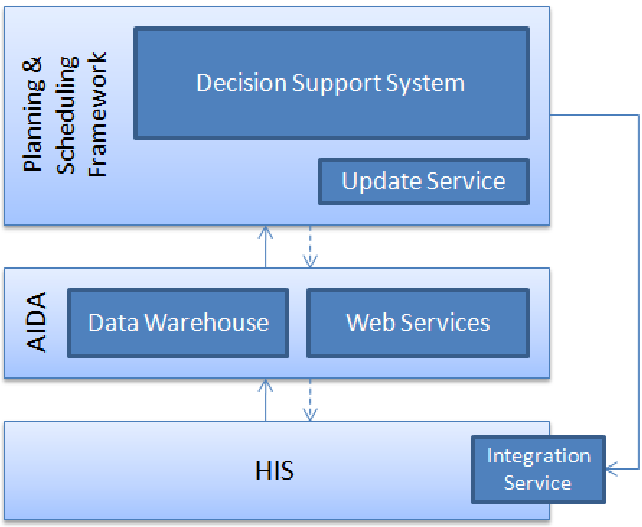

Fig. 1. Architecture diagram depicting the HIS, the interoperability layer (AIDA) and the DSS. The dashed arrows represent an information request, while the solid ones means a tier is sending data to another. The solid arrow on the right side represents the process of writing data into the HIS, which is managed by an integration service provided by the HIS.

4 A Decision Support System for Scheduling Elective Surgeries

This decision support system is part of an ongoing project with two distinct stages. In the first stage, which we are presenting in this paper, the goal is to provide a system to support the manual process of planning and scheduling elective surgeries. In a subsequent stage we will incorporate simulation, optimization and data mining modules into the system, in order to add an intelligent component into the DSS.

We stress that although the system was built in close cooperation with a public hospital, it was designed with the goal of being generic and adaptable to others. In this section we will present the main characteristics of the DSS and we will report our experience on its initial deployment.

4.1 Features

A decision support system is aimed at helping decision agents to better evaluate their options, sustain and select the right alternative. In general, public Portuguese health system lacks such mechanism when realizing the surgery scheduling plans.

The goal of our DSS is to make available a framework which integrates all the necessary information for devising the weekly surgery scheduling plans and provide an appropriate set of functionalities and constraints validation mechanism. This project has been performed in strict collaboration with one of the biggest hospitals in the north of Portugal, allowing the team to gain a fundamental understanding of the surgery scheduling process and the corresponding information needs. As such, we incorporated many features requested by surgeons and included features that are focused in overcoming problems detected on the system currently in use.

The proposed DSS is an integrated system made of 3 main modules: (i) resource management; (ii) surgery planning and scheduling; (iii) performance measurement.

The resource management module is to be used by the surgery theatre managing staff and groups the features required to configure and allocate the necessary resources. Examples of resources are the operating rooms, medical specialties, surgeons and users of the system. The surgery theatre manager has to configure the existing resources and create a periodic master surgery schedule. Our DSS enables the flexible creation of weekly plans, plans for an arbitrary number of weeks and also the allocation of specialties to operating rooms.

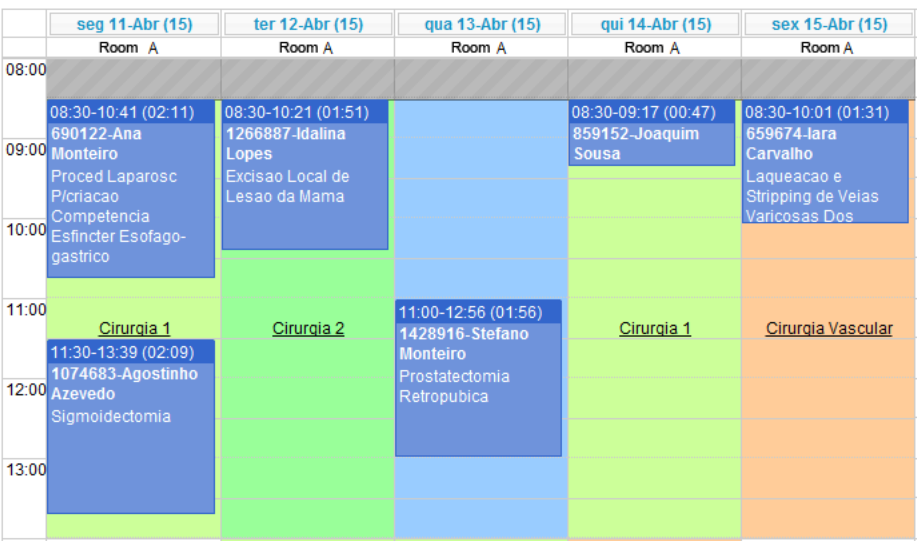

Fig. 2. Overview of the weekly surgery schedule for a certain operating room. In this particular example, each day corresponds to a different surgical specialty and each block equals a surgery and includes the patient identification, name and procedure. Compared to the current system, this enables a better perspective of the entire weekly plan, where in the former only a daily view is available.

The surgery planning and scheduling module is the core of the DSS and makes available a set of features to schedule surgeries. The surgery scheduling interface (see Fig.2) supports the daily/weekly process of scheduling surgeries. It is used mainly by surgeons and administrative users and was created based on the needs of those users to be as functional and easy to use as possible. This agenda shows the operating rooms available for a user's specialty and allows a weekly or daily perspective. The weekly view is suitable to have a global insight of one or two rooms and the daily view is adequate to have a side by side comparison of multiple rooms.

Regarding the patients' waiting list for a specialty, two features were specially welcomed by the surgeons: a color scheme that highlights patients according to the time left relatively to the waiting time limit and the possibility of filtering the waiting list by the estimated surgical procedure time duration. The latter, gives the means to rapidly identify a surgery adequate to fill a gap in the planning horizon. Details about surgeries and patient information are also easily accessed on the interface. Finally, a non-obstructive notification system was created that provides alerts when some operational restrictions are violated. For example, a notification is issued when the expected time duration for the planned surgeries exceeds the limits of the period allocated to the corresponding specialty or when the scheduling violates the patients' priorities.

The third module concerns the processes of results evaluation and KPIs (see Fig. 3) that can lead to the identification of opportunities to improve operational performance. A set of customized charts is provided that is configurable according to the user profile, such as: operating room/specialty utilization rate over time, the evolution of the waiting list over time and the number penalties due to the violation of priorities over time.

Currently, the DSS is able to help the users to better manage the scheduling planning process. The long term benefits expected are fewer penalties due to policy compliancy, reduced waiting lists for surgery and better utilization of surgery theatre resources.

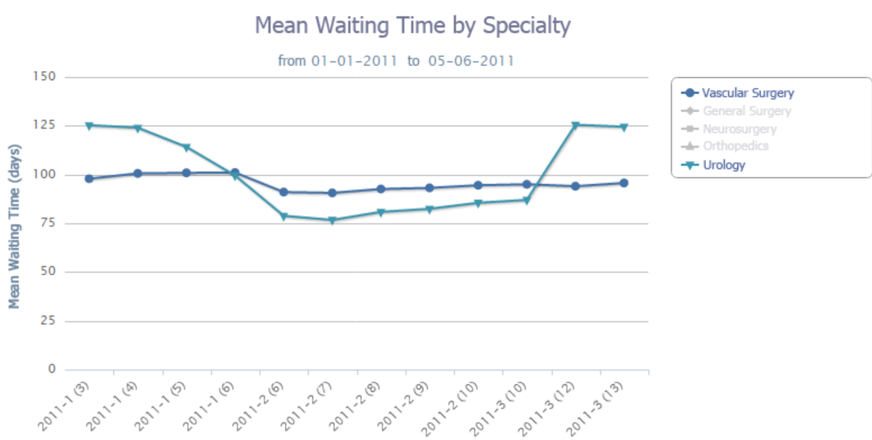

Fig. 3. Weekly chart of the mean waiting time for surgery of two surgical specialties. Several other key performance indicators are available, which are recorded daily and can be aggregated weekly, monthly and yearly.

4.2 Case Study

Throughout the development of the DSS we had several interactions with surgeons and hospital management staff. Our project was implemented as a pilot in two surgical specialties, which collaborated iteratively during the development and testing phase. Surgeons and administrative staff feedback was collected during regular meetings at the surgical services facilities, benefiting from each specialty's weekly gathering, so that every user could evaluate the system and follow up with its development. On the other hand, the integration task required the support of hospital's information system department staff, which provided access to the communication tier AIDA.

Along with the development and integration of the system, the results of a study conducted by a third party on this hospital, concerning the time durations of surgical procedures was implemented into our system (see Fig. 4). However, the study was only based on the medians of the completed surgeries durations records. In the future, we aim to improve the estimates by testing and applying data mining and regression techniques to model the procedures duration.

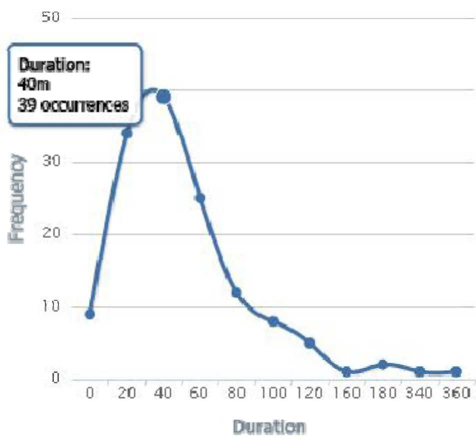

Fig. 4. Frequency distribution of one surgical procedure time duration. This information might help the surgeon to define the expected time duration of a surgery.

As a preliminary result, it was noticeable a drop on the average waiting time for surgery of one of the pilot specialties (125 to 75 days). The transition from the traditional planning environment to our system lead to the scheduling of many surgeries already planned. Additionally, we have noticed that the system brings more transparency to the scheduling process, making it easier to identify improvement opportunities (low occupancy rate operating rooms), or even correct simple administrative errors that could result in penalties to the hospital (patients that canceled the surgery are still on the waiting list).

The final deliverable is a surgery theatre decision support system, based on the hospital's scheduling process and user feedback, aiming at improving efficiency and quality of service. The next step will be to prepare the remaining specialties to use the DSS for their planning activities.

5 Conclusion

In summary, this paper reports the development of an integrated decision support system which intends to support the process of surgery theatre planning and scheduling. The DSS was developed using a user centered approach based on a traditional software engineering lifecycle model and it is composed of modules for resource management, surgery scheduling and performance measurement.

The system developed uses current web standards to allow an easy deployment in any hospital organization. Due to its independent and modular architecture, the system can be easily integrated with the hospital information system architecture and allows the independent development of new features.

A case study is presented reporting the experience of deploying the platform in a large public hospital, in which the DSS has already proven to be useful, by helping to lower the mean waiting time for surgery of one specialty.

As future work, we plan to continue to diversify the range of components available and the techniques employed to aid the decision process. Following the approach proposed by [15] we are studying the integration of three modules of data mining, optimization and simulation. The next step will be to study the surgery theatre planning problems, briefly described in this paper, in order to create mathematical models that describe the surgery theatre system. The use of data mining techniques will allow us to constantly characterize the stream of information and tune the optimization and simulation models. These techniques, when integrated in the DSS will provide the decision agents with greater knowledge of the system, anticipating possible events and, eventually, achieve better performance, creating competitive advantages.

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Data Acquisition Process for an Intelligent Decision Support in Gynecology and Obstetrics Emergency Triage

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Abstract. Manchester Triage System is a reliable system of triage in the emergency department of a hospital. This system when applied to a specific patients' condition such the pregnancy has several limitations. To overcome those limitations an alternative triage IDSS was developed in the MJD. In this approach the knowledge was obtained directly from the doctors' empirical and scientific experience to make the first version of decision models. Due to the particular gynecological and/or obstetrics requests other characteristics had been developed, namely a system that can increase patient safety for women in need of immediate care and help low-risk women avoid high-risk care, maximizing the use of resources. This paper presents the arrival flowchart, the associated decisions and the knowledge acquisition cycle. Results showed that this new approach enhances the efficiency and the safety through the appropriate use of resources and by assisting the right patient in the right place.

Keywords: Triage, Emergency Department, Intelligent Decision Support Systems, Manchester Triage System.

1 Introduction

Typically, in medical emergencies, triage is the process of determining the priority of patients treatments based on the severity of their clinical condition.

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There are various types of triage systems and the most commonly used are those with five levels of severity, such as the Emergency Severity Index (ESI) [1], the Manchester Triage System (MST) [2] and the Canadian Triage and Acuity Scale (CTAS) [3].

Maternidade Júlio Dinis (MJD) is a maternity hospital that provides care for women during pregnancy and childbirth and for newborn infants. In the Emergency Department (ED) of MJD, women who seek Gynecological and/or Obstetrics (GO) emergency care (pregnant, non-pregnant, parous or primiparous) pass by a triage system specially developed for GO, which is presented in this paper.

Previously, they were also assisted in the ED of Hospital Geral de Santo António (HGSA) using the MTS, which hasn't been effective for GO due to the generality of the questions used for the triage. However, there was still the need for a triage system in MJD because the misclassification of non-urgent patients has been pointed as a problematic aspect in emergency settings when patients severity is not identified at triage, or if there is no accordance on what problems are non-urgent. [4-7].

Furthermore, there are numerous limitations associated with the process of validating triage scales. Even in developed countries, there are problems in conceptualizing validation methods [8]. Moreover, it is known that several maternal symptoms require special evaluation. It should also be stressed that the limited budgets for health care make crucial to prioritize patients' needs and assist them with the most appropriate resources.

The above pointed restrictions motivated the development of a triage system specific for GO that supports the decision-making process for a better healthcare in MJD by distinguishing urgent and non-urgent patients. An Intelligent Decision Support System (IDSS) is in construction to support this process through the use of the knowledge discovery and data mining techniques to predict the level of urgency and help to choose the better decision for each situation.

The paper is divided in five chapters. The first one introduces the MJD, the MST and the IDSS. The second one presents the actual context and the foundations for triage and how Manchester System works. The third chapter outlines the IDSS implemented for the GO purposes, the main objectives and changes occurred. An illustrative example is used to explain the GO Triage process. The fourth part of this paper presents some qualitative and quantitative results obtained so far. Finally, some discussions and conclusions are made.

2 Background and Related Work

2.1 Context

MJD is part of Centro Hospitalar do Porto (CHP), together with Hospital de Santo António (HSA) and Hospital Maria Pia (HMP). CHP was created in 2007 and, prior to that, the three were separated entities. Women in need of urgent Care (GO) could attend the ED of either HGSA or MJD. Since the creation of CHP, women in such conditions are encouraged to attend the ED of MJD instead of HSA (ex-HGSA).

HSA has a general ED working with the MTS since 2000 and, to optimize the care provided to women in urgent or emergent situations, they are sent to the ED of MJD with a specific triage system that we developed, which is in use for six months, since January of 2010.

2.2 Intelligent Decision Support System

According to Turban [9], a decision support system is an interactive, flexible and adaptable information system, developed to support a problem solution and to improve the decision making. These systems usually use artificial intelligence techniques and are based on prediction and decision models that analyze a vast amount of variables to answer a question.

The decision making process can be divided in five phases: intelligence, design, choice, implementation and monitoring [9]. To be an IDSS there exist some features that have to be accomplished. [10] The presence of an IDSS on an ED permits a better understanding of the real state of the patient and can improve the output results, because it can help the nurses giving the best care to the women on the time that they needs.

2.3 Triage

Triage is a process developed with the agreement of a panel of experts based on decision rules and is an integral part of the modern ED [11]. It is mostly supported by computerized information systems [12].

In the triage process, decision-making involves the interpretation, discrimination and evaluation of communication between the patient and the health care providers that are carrying out the triage process [13].

Good decision making is crucial because patient outcome is greatly influenced by the initial assessment of the triage. The main method used in the triage process by the professional community in HSA is the MTS, which is described in the next section.

Additionally, it is explained why this system does not fit urgent and emergent situations for GO and is presented the system we developed for that purpose.

Obstetric triage has been one of the latest obstetric services to emerge throughout the last decade and hospitals have incorporated triage principles into the practice of GO [14].

GO triage occurs in a women's hospital emergency unit, where a variety of GO conditions are presented, since labor assessment and assistance to common GO conditions. It is, therefore, of great importance to ensure that women who attend the triage unit are properly evaluated and that high-risk patients are accordingly treated, not just the mother, but also the fetus.

According to the severity level allotted to the patients in the ED, they are assigned to the appropriate observation area and the first observation should occur in a defined period of time.

The purposes of ED triage are described as “assigning the patient a place in queue, assigning an area or treatment room, predicting resource consumption and identifying non urgent patients who could be diverted to other, presumably less expensive venues” [15, 16]. Likewise, triage for GO has the ability to screen, prioritize, and expedite GO conditions, and is used to rate the severity of women’s condition and to optimize the resources available, for the resources of ED can be overused for non-urgent patients.

This ability also lends itself to the emergent care skills needed in an obstetric triage unit as well as effective triaging [17].

In conclusion, the main concerns in triage, either in GO or in other medical specialties are to improve the quality of care and reduce the risks arising from the waiting time to emergent care. Discrepancies in triage may lead to inappropriate use of resource and may contribute to both patient and staff dissatisfaction.

"If overtriage occurs, excessive resources are used for patients with nonurgent problems, resulting in excess costs and delays of care for the patients with more severe problems. If undertriage occurs, potentially sick patients may be triaged as nonurgent resulting in a clinically unsafe diversion from the ED." [4].

2.4 Manchester Triage System

The Manchester Triage System (MTS) [2] is a five point triage scale used to triage patients presenting to the ED, which was introduced in the United Kingdom in 1996 and is now widespread, especially in Europe, and has been in use in HSA since 2000.

Although the MTS is a reliable system of triage in the ED, well suited for general emergency situations, in particular cases like the GO care, its use is unsatisfactory due to the generalization of the questions it uses for classifying patients' clinical severity status. This system workflow confines to a number of presenting problems with associated flowcharts and supporting documentation. It has five levels of classification. Table 1 presents the five levels of classification of the MTS and the corresponded recommended waiting times for patients.

Table 1. MTS levels and recommended waiting times [18]

Levels	**Patient should be seen by provider within**
1 – Immediate	0 minutes
2 - Very urgent	10 minutes
3 – Urgent	60 minutes
4 – Standard	120 minutes
5 – Nonurgent	240 minutes

The benefits of the MTS were examined and considered to overcome other systems [13]. Some advantages were identified, highlighting the fact that the MTS is a method of triage internationally recognized, reliable and professionally evaluated and successfully used in a number of different health care systems.

Although the literature states that the MTS is a suitable evidence-based triage method and could be expanded to include other EDs of band one hospitals [13], it is not suitable to ED for GO, as experienced in HSA. Discussions arose that led to the conclusion that the criteria document that supports the MTS system did not satisfy the requirements for emergency care in GO.

MTS is simple enough to allow a quickly assess of the patients' clinical condition and is applicable for the wide-range population with a large variability in signs and symptoms in the emergency care setting [11].

Therefore, its use is more suitable for general medical emergencies and not the specific emergencies of women in need of GO medical assistance.

Furthermore, the discriminatory power of MTS is not equal for medical and surgical specialties, which may be related to the character of its natural discriminators [19].

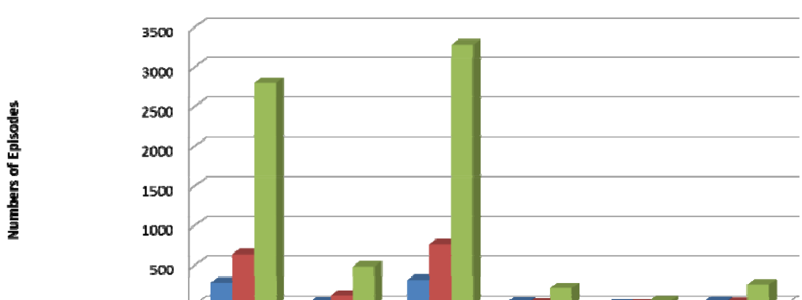
Triage is a process developed with the agreement of a panel of experts based on decision rules and is an integral part of the modern ED [11]. It is mostly supported by computerized information systems [12].

In the triage process, decision-making involves the interpretation, discrimination and evaluation of communication between the patient and the health care providers that.

3 Triage System for Gynecology and Obstetrics in MJD

Prior to the creation of CHP, pregnant women and women in need of urgent or emergent care were admitted in HGSA and MJD for emergency situations. In HGSA, the MTS had been used since 2000. However, the healthcare professionals realized that the MTS was not adapted to the GO service due to the degree of generalization of the questions. Moreover, more than 40% of the cases were not emergencies, which would translate in a misuse of resources. Accordingly, we developed a triage system specific for GO, where the questions are focused on that particular type of patients, i.e. pregnant or parous women. After the creation of CHP, GO emergencies were transferred to MJD with the new triage system.

As depicted in the graph of the Fig. 1, a decrease of 85% in GO emergencies episodes occurred in the first six months of 2010 when compared with the same period of 2009.



	2009 Gynecology	2009 Obstetrics	2009 Total	2010 Gynecology	2010 Obstetrics	2010 Total
Outpatient - Total	284	33	317	31	7	38
Inpatient Services - Total	640	124	764	18	6	24
Total	2799	484	3283	213	49	262

Fig. 1. GO Episodes in CHP

We developed an effective triage model that meets the needs of the ED for GO, particularly a system that can increase patient safety for women in need of immediate care (proving) and help low-risk women avoid high-risk care, maximizing the use of resources.

The goal of this system is to classify patients according to the severity of their clinical condition, establishing clinical priorities and not diagnosis.

The triage is done by specialized physicians and is based on a set of predefined questions in the form of rules of a decision tree. According to the result, the IDSS indicates whether the patient should be sent to an urgent (URG) or normal consultation (ARGO - Outpatient Clinic). Women in need of urgent care (e.g. women who arrive by ambulance in very serious conditions) are immediately assisted, without any triage.

Before, in MJD, patients were admitted in the order of their arrival, not differentiating the cases that required immediate or intermediate assistance and the non-urgent cases. In HGSA they were classified with the MTS.

The IDSS brought some improvement in healthcare, essentially because:

- Contributes to the decrease of clinical errors;
- Provides cost-effective and proper care;
- Improves client satisfaction.

Moreover, by transferring all the GO emergencies to MJD and correctly assessing their severity, it also contributes for reducing overcrowding of ED [20-22]

When women arrive at the MJD requiring urgent observation, and before any admission paperwork, a physician makes the triage using the system. It indicates if the patient should be assisted with urgency or be sent to a normal first medical appointment.

In opposition to the MTS, triage is done by physicians and not by nurses. In general ED triage, nurses usually gather the clinical information and make the triage decision.

However, tests in MJD showed a lack of agreement in triage assessment between nurses and doctors. Moreover, a study showed that the triage decisions physicians make are significantly different when they have and take the opportunity to visually evaluate patients [23].

Accordingly, a visual assessment can enhance the doctors' intuitive ability to quickly distinguish a sick from a not-so-sick patient. In conclusion, close supervision by a doctor is essential because of the significant risks involved [24].

The flowchart (fig. 2) describes the real-time decision process, in ED, after some woman arrive to MJD.

In the future we will use the results of questionnaires and consultation and the decisions made during the experimental period to create prediction models in order to accurately discriminate the urgent cases, dividing the actual urgent class in two subclasses: urgent and can be urgent.

The last type of patients (can be urgent) will be directed to a normal consultation. During the waiting time they will be in observation and if something happens aggravating the clinical condition, the priority will be changed to urgent and the patient will be immediately assisted.

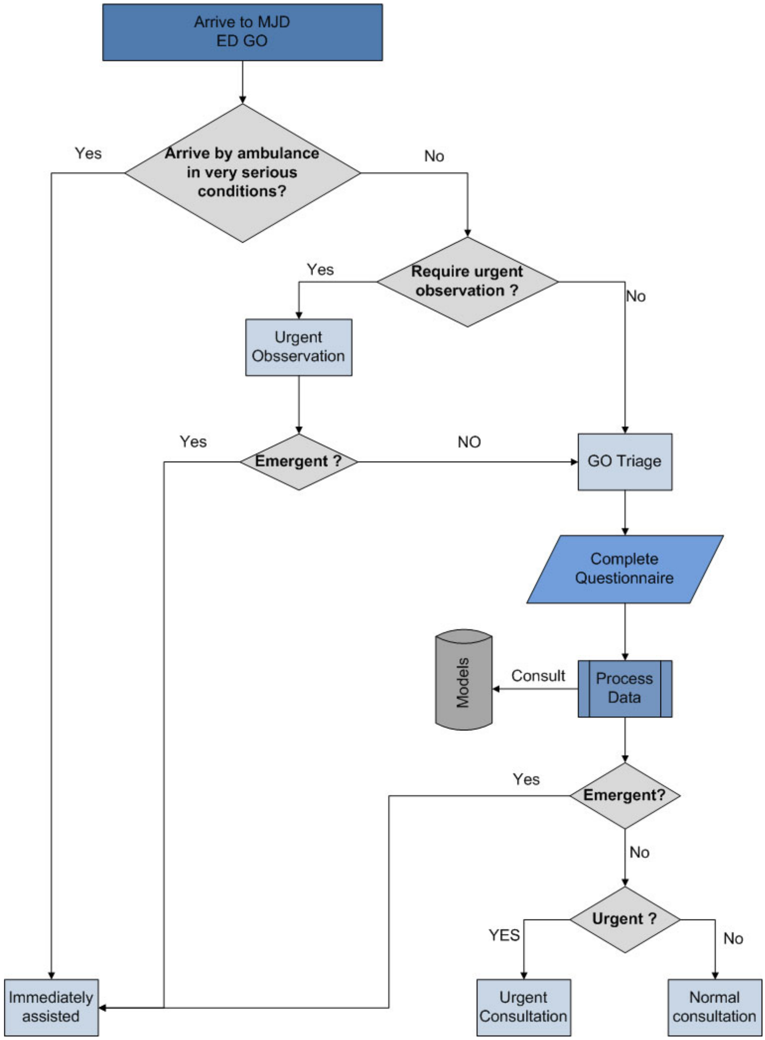


Fig. 2. GO process

4 Results

The system has been at work since January of 2010. In six months, 9959 women passed by the triage system. Figure 3 shows the distribution of the population by the two possible categories of the triage – ARGO and URG.

Accordingly, almost 50% of the cases (4299) were classified as non-urgent (ARGO) (FIG.3), which means that those women were sent to a normal first medical appointment, reducing ED overcrowding and contributing to a better efficiency.

Without this system, all women would have been assisted with urgency, according to their time of arrival, not the severity (or lack of) of their clinical condition.

The effects of this scenario would be misuse of resources and potentially more urgent cases could be assisted after the less urgent. It is also worth noting that, in six months, near 10000 women was assisted in MJD, contributing to less crowding in the ED of HSA.

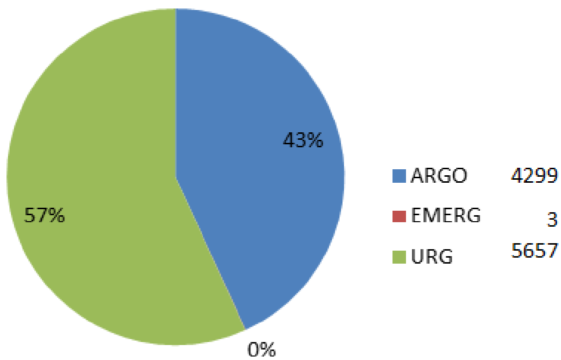


Fig. 3. Results of the triage system

Fig. 4 shows the distribution of the possible causes pointed by the patients as the motivation to come to MJD. As we can see 35% of these women are not pregnant and some of those women need to be observed in other units like Institute of Gynecology and Obstetrics (IGO).

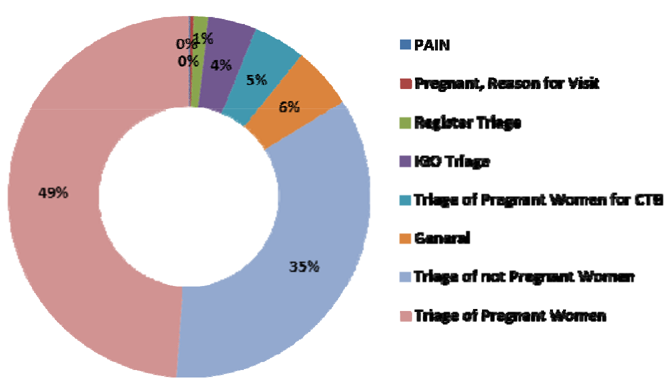


Fig. 4. MJD Triage type

The modification introduced in the mode the triage was done increased the number of the first consults reducing the waiting list.

This improvement turned CHP eligible to receive a money prize, by the Health Ministry, as a performance bonus to ensuring greater accessibility to special care (Outpatient Clinic).

5 Discussion

Even though it is a two-level system, in opposition to the prior system with a five-scale (MTS), the new system has proven to be more effective and brought benefits in healthcare of GO emergencies, in comparison to the previous one, where the attendance was done by arrived order and however sometimes was analyzed the clinical risk.

Patient priority is defined by the classes' urgent or first medical appointment. Although it is not a class, emergent cases have the highest priority and are sent immediately for the observation room, with no need for triage.

With this strategy it is guaranteed that resources are optimally used and that women are assisted accordingly to the urgent degree of their medical condition, which has been pointed as major issues in triage systems.

6 Conclusion

Some important changes were made. With this system the ED professionals can better assist the patients according to their urgency i.e. if some case is really urgent (emergent) is because is very danger to patient health and will be treated instantly.

With these options we can have three types of patients: Emergent, Urgent or Normal, and they will be observed / attended with the level of risk. The IDSS help the nurses to make the better decision according some decision rules that in the future will be integrated in the prediction models.

With this changes we can prove that the use of clinical knowledge of this specific area allow to have a system more suited to this type of users, contrary to what it happened previously.

Like we showed GO benefits from the adoption of the IDSS. The future work includes the use of the data collected to optimize the rules and the data mining models as a way to improve the IDSS performance and to generate more accurate knowledge.

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Enabling a Pervasive Approach for Intelligent Decision Support in Critical Health Care

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Abstract. The creation of a pervasive and intelligent environment makes possible the remote work with good results in a great range of applications. However, the critical health care is one of the most difficult areas to implement it. In particular Intensive Care Units represent a new challenge for this field, bringing new requirements and demanding for new features that should be satisfied if we want to succeed. This paper presents a framework to evaluate future developments in order to efficiently adapt an Intelligent Decision Support System to a pervasive approach in the area of critical health (INTCare research project).

Keywords: Intensive Care, Pervasive Environments, Critical Health Care, Intelligent Environment, Real-Time, Online, Remote Connection.

1 Introduction

INTCare [1-4] is an ongoing research project involving the Intensive Care Unit of the Porto Hospital Centre whose objective is to implement an Intelligent Decision Support System (IDSS) to predict the dysfunction or failure of six organic systems and the patient outcome in order to help doctors deciding on the better treatments or procedures for the patient. The good results obtained so far [5-7] motivated the transformation of this system into a pervasive IDSS. A framework to evaluate the efficacy of the new characteristics has been developed as a way to attest their feasibility. A Critical Environment has special characteristics and needs, such as fast, efficient, secure and ubiquitous operations in real time. At the moment, we choose the ICU to make our tests. ICUs are considered a critical environment because they have some complex health care situations [8]. The activities occurring in it are sometimes adverse, dangerous and tiring. and the various organ systems of the patient may be affected at the same time [9] what represents a challenge for the systems [8] that operate in this environment. The ICU main objectives are diagnose, monitor and treat patients with serious illnesses and recover them for their health previous state and quality of life [10]. With the introduction of Intelligent Environments (IE) this type of

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monitoring could be done remotely. These operations could be supported by the new technologies based on Pervasive Healthcare Computing that allow the execution of remote tasks (access and control).

Pervasive HealthCare can be defined as "healthcare to anyone, anytime, and anywhere by removing locational, time and other restraints while increasing both the coverage and the quality of healthcare" [11].

A pervasive medical environment is designed to allow smart interactions by mobile devices with the patient sensor and data servers. Is imperatively necessary help the doctors make the best decision and take a pro-active attitude in the patients' best interest [1, 12]. For this is important that medical staff have all important and essential information, in real time, online, and in electronic format. The best solution is modify the environment paradigm, making it intelligent, where all information will be available at the right time and the right place, eliminating any kind of barrier either be it time or place. This is very important because the communications between health care professionals represents a large part of their activity [13]. This development aims the remote access to the health data and future predictions of patient conditions made available by the INTCare system, guarantying the maximum quality, security and privacy.

The main objective of this paper is to present the requirements that should be addressed in order to bring pervasiveness to an IDSS and an evaluation framework in order to guarantee the results. This paper is divided into eight chapters. The first one introduces the necessities of the new environment and the motivation of the work, the second gives an idea about what is the INTCare system. The third one presents the environment evolution, comparing the past (*As was*) and the present (*As is*). The forth chapter presents the main features necessary to enable a pervasive environment. In order to evaluate the implementations, the chapter five proposes a framework to evaluate the environment. At the end, some discussion about the significations of each result will be done, including conclusions and future work.

2 Background

Like Roy and Das [14] told: "The essence of pervasive computing lies in the creation of smart environments saturated with computing and communication capabilities, yet gracefully integrated with human users (inhabitants)". Nowadays, we can verify that pervasive and ubiquitous computing and ambient intelligence are concepts evolving in a growing number of applications in health care and the influence of it increase every days [15]. Some similarities can be found in other study [16] related to the developing of pervasive computing: there will be an evolution from isolated "smart spaces" to more integrated Hospital environments, which can be accessed remotely. The necessities are global and the medical staffs "require" information about their patient available through the world and, if possible, with some patient condition previsions to help in the decision-making process. An intelligent and pervasive environment requires that a large number of tasks could be done automatically and the information should be accessed electronically. however the Health Care providers are registering, manually, the patient characteristics into the computer system, hindering automation of some tasks like the retrieval, registration and display of information [7].

INTCare is IDSS that is prepared to work in critical environments and are being modified to also be pervasive. This IDSS is implemented in terms of a Multi Agent System in order to process some tasks automatically and to ensure their success. The flexibility of such approach makes the incorporation of new agents to integrate the IDSS in the Pervasive Intelligent Environment an easy task. INTCare is capable of predicting organ failure probability and the outcome of the patient for the next hour, as well as the best suited treatment to apply[17] .

To achieve this, it includes models induced by means of Data Mining techniques [12], [4, 18-20]. This system has so particular Features [17] that allow operate in pervasive environment: Online Learning, Real-Time, adaptability, Data Mining and Decision Models, Optimization and Intelligent Agents. Now some pervasive and ubiquitous characteristics are being added.

3 Pervasive Environment

The objective is to create a “smart environment” able to operate autonomously, prepared to acquire and apply knowledge about its users and their surroundings, and adapt to the users’ behaviour or preferences with the ultimate goal to improve their experience in those environment [21], facilitating the mode how they work and improve the patient condition. To do this, we had to understand *as was* the environment and define the necessary modifications to make it pervasive (*As is*). Accomplishing these changes we are extending the existing environment in order to turn it prepared to an automated information system for ICU taking into account the harmonisation with the whole information system and activities within the unit and the hospital [22].

3.1 As Was

The project started in 2008 and during this time some important steps were given: transforming a paper based and manual process information system to an automatic and electronic one. The data was collected in offline and in an irregularly mode making the analysis of patient data and the search of past information a very hard and time-consuming work. The existing information systems were only used information consultation and not to register patient data. For example the bedside monitors only showed patient vital signs (VS) values, these weren't stored in any place. In fig 1 is visible how Medical Staff have been working in the ICU. Normally they analyse the patient condition, looking for the VS values from the bed side monitors and, every one hour, they wrote the results in the Paper Based Nursing Record (PBNR). After that, the PBNR values were made available to be analysed and stored manually into tables. The Lab Results constitute another important data source being collected, in average, one or two times a day. The data was only available to be consulted in pdf format only 2 hour after the measuring. To store the results into a database the medical staff should read the documents and insert, manually, the values into the tables. Only after this process the patient information will be available in the database (DB) and in electronic format. This process was very inefficient and was the origin of many errors.

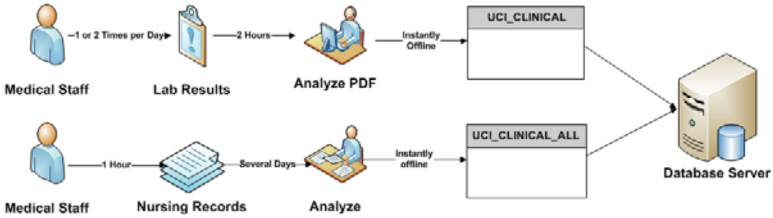

Fig. 1. ICU Past Environment

3.2 As Is

After some interactions with ICU staff and some analyses of the environment, we defined the necessities and requirements for the ICU. We had to change several processes and reformulate the information system (IS) architecture. Along the last three years we introduced a lot of modifications into the IS architecture [17, 23]. In particular some intelligent agents were designed to do some tasks automatically and replacing some manual operations. "Intelligent agents with their properties of autonomy, reactivity, and proactivity are well suited for dynamic, ill-structured, and complex environments" [24], such as an ICU. The system actually working in the ICU environment can perform all tasks in online, real-time and electronic mode. The agents are used to perform automatic tasks like collecting and storing patient data. The intelligent agents collect data from four data sources: Electronic Health Record (EHR), Lab Results, Vital Signs and drugs system. All data is received and send, automatically and at the same time, to the Electronic Nursing Record (ENR).

ENR is a system which was developed with the objective to receive all medical data and put it available to Doctors and Nurses (responsible to consult and validate the data in an hourly-based mode). It is a mechanism to integrate and subsequently access patient data. The digital nature of an ENR allows data contained within it to be searched and retrieved [25]. When some data errors appear, they should be corrected putting the exact values on ENR. On the other hand, we have some data that are still collected manually; this data is registered by the doctors or nurses and is concerned to three information's types: procedures, adverse events and some nursing records like fluid balances.

These types of operations normally are not programmed and are done by the nurses near the patient. The use of ENR improves the data quality and reduces the number of unidentified patients in the monitoring system [5]. When the data is valid, it should be stored into the database. With this process we can ensure that the data that are available in the environment are real and are correctly associated to the patients.

The fig. 2 outlines the actual reality of ICU. Like the figure shows the environment has changed, and now only some tasks are manual. Be noticed that the data validation kept manual because only the humans can see if the data associated to some patient are correct or not (due to the semantics associated to clinical interpretation).

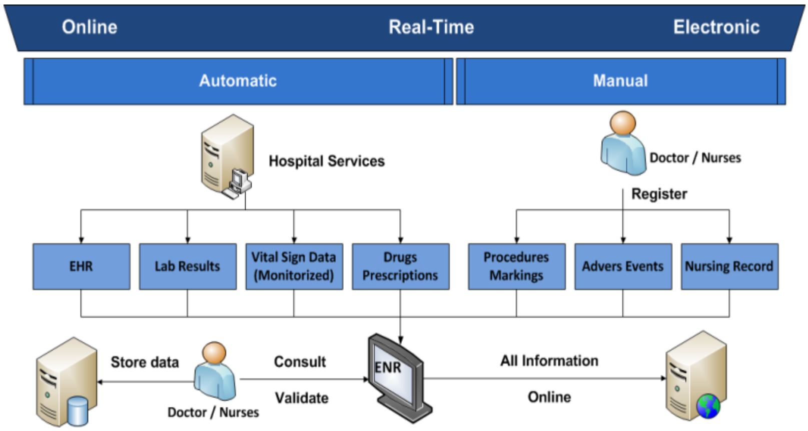

Fig. 2. UCI Current Environment

4 Environment Features

In order to set up the environment to an IDSS like INTCare, some features of the system [17] need to be assured. The main features for this environment are:

a) ***Real Time***: All patient data have to be collected in real-time for that some patient sensors have to be added to ICU. Is necessary creates some control tasks in the Environment to ensure that the manual data are inserted in database, as immediately as possible, after the events occurs.

b) ***Electronic Mode***: In this environment all data have to be available in electronic mode for this the nursing staffs has to verify if all data have electronic access and if not, they have to register the manual data in ENR.

c) ***Online***: The information of each patient need to be available online, i.e. all data have to be accessed through the ENR independently on the environment type.

d) ***Autonomous***: It has to have as many as possible automatic tasks. Almost all of the tasks in the environment can be performed automatically by Intelligent Agents, however is very important that data validations continue to be manual operations.

e) ***Safety***: *A*ll patient data presented on database and servers have to be safe and protected. The data security has to be ensured and nobody without access can consult the data. This is the one of the most critical aspect in these environments.

f) ***Reliable***: This aspect has two types. The first, the nurse staff is responsible to validate the data, in ENR, moments after collection. The second, the systems that will operate in these environments only can see the data that it looked for. With this, the user is sure that the data he can see online is guaranteed true.

g) ***Accurate***: All operations have to be approved before someone does something. The tasks have to be good defined and precise, i.e. the operation have to be valid and never can put the patient in risk. With this is possible avoid any phishing.

h) ***Privacy***: There are two types of privacy: the patient and the health care professional. PID always has to be hidden to people out of hospital. On the other hand all tasks done on this environment need to be identified and associated to one person. With this we can know who did the operations and blame for something that happened.

i) ***Adaptive*****:** The environment has to be the capability of adapt to the change of some variables, always ensure the proper functioning of the same. Sometimes is necessary optimizing some tasks and the system have to be prepared for that. If this is possible this type of operations should be performed automatically.

j) ***Secure Access*****:** The hospital access point has to be protected and encrypted. A virtual private network with access protocols is essential because this type of operations have to be secure. Only people who have access to the ICU can see the information and operate, local or remotely, in this environment. Is extremely dangerous if foreign people accede to the hospital and see what they can't see

k) ***Context awareness*****:** is concerned with the situation a device or user is in, and with adapting applications to the current situation [14]. All users need to be focused on the environment and to know the importance of the success of the operations because there can't be any type of negligence.

l) ***Risk List and Contingence Plan*****:** This is a critical area where anything can fail. Is necessary to predict some problems, define the risk impact, the happen probability and prepare some contingence task.

If the aspects safety (e), privacy (h), and secure access (j) aren't always guaranteed is better not do nothing, because any type of operations can put in risk the patients, the hospital and all people that operate there. The other important aspect is the Effective data consistency since it provides the foundation to ensure that medical practitioners receive up-to-date a correct data on time, whenever they need [26]. This type of environments have to be concerned with the safety of users, reduction of cost of maintaining the environment, optimization of resources task automation or the promotion of an intelligent independent living environment for health care services and wellness management [10]. An important characteristic for the pervasive environment lies in the autonomous and pro-active interaction of smart devices used for determining users' important contexts, realization of tasks, consults of vital sign and patient information, which ensure the success of distance operations. Our environment aims to support web applications for different platforms in order to allow users to access the application using one portable device (laptop, mobile, PDA).

Fig. 3. Hospital Pervasive Access

Now, at any time, the user (ICU professional) can consult patient's information by some device regardless of where he is. Like was presented before [7] exist many possible communications in the Hospital throughout the world. However is necessary to make some modification in the architecture with the objective to enable a secure connection. The fig. 3 illustrates the alterations introduced, the doctors only can connect to the hospital through online applications in this case the interface will be the ENR. ENR gives the possibility to put, online, all data about the patient. This data will be validating by the doctors / nurses that are present in the ICU and near the patient. The connection is protected and only users with access privileges can connect to the hospital and see the data. This group will be limited and if someone needs access to the system, have to request access to the team in charge of the ICU, with this option we can control who is accessing to the system remotely. Out of the ICU the doctors only can consult the data; the validation is not possible because they are so far the patient. The patient is in ICU on Porto, doctors make a secure connection to the hospital, regardless of where they are, the time at which they are accessing and the device they are using, they can consult and analyse patient data. If they see something wrong like bad lab results, bad prescriptions, bad previsions or anything else, they can use a collaborative platform and talk with other specialists about what is the best decision / treatment to apply to the patient. In this task, INTCare can be a good help because it gives the best decisions based in some previsions and earlier treatments to particular patient problems. After the decision, this can be communicated to someone on ICU to accomplish it, may be given an instruction to the system to make an autonomous operation, can be made some treatments changes, or can be prescribed new drugs through drug system. All decision and their results will be stored in database with the objective to improve the decision; this requires an adaptation of the predictive and decision system.

5 A Framework to Evaluate Environment Quality

An important issue is the evaluation of the proposed approach in order to determine its efficiency. The evaluation should incorporate two strands: technical and human. The data from the remote connections will be used to support the technical evaluation. A framework will be defined in order to facilitate the users giving their opinion about their interaction with the environment. The results obtained will be submitted to a panel of experts from several areas (e.g. Information System, Communication, and Health). The system will start working for tests very soon; we are making the latest implementations and modifications in the ICU. This framework considers a set of measures and a scale of possible answers. The scale ranges from one (R1 – the lowest level) to five (R5 – the highest level). Each measure is then associated to particular range, e.g., data access has three possible options R [1-3], and the Reliability System has five possible answers, R [1-5].

5.1 Surveys

To the human evaluation we consider some online questionnaires that will be concerned with the connection (A), the data (B), and the environment and user satisfaction (C). The table 1 shows the measures and the evaluation scale of each.

Table 1. Environment Evaluation Measure

Measure		Evaluation Scale				
		R1	**R2**	**R3**	**R4**	**R5**
Connection Secure	A_1	No	Yes			
Connection Velocity	A_2	Too Slow	Slow	Normal	Fast	Very Fast
Data Access	A_3	Many Delay	Some Delay	Just In Time		
Reliability System	A_4	None	Little	Some	A Lot	All
Privacy	A_5	No	Yes			
Data Accuracy	B_1	50% or less	51% to 75%	76% to 99%	All	
Electronic Data	B_2	50% or less	51% to 75%	76% to 99%	All	
Online Data	B_3	50% or less	51% to 75%	76% to 99%	All	
Access	C_1	Difficult	Normal	Easy		
Adaptive Environment	C_2	No	Yes			
Interface	C_3	Very Bad	Bad	Good	Very Good	Excellent
Global Satisfaction	C_4	Very Bad	Bad	Good	Very Good	Excellent

5.2 Results Analysis

Understand the environment, realize if it is really intelligent and verify if is working as expected, is the base of success of a pervasive environment. The questionnaires will be filled by people that interacted with the environment inside and outside of ICU. The table I configures the base of the evaluation framework. In this table a scale of measures was defined ranging from R1 (min) to R5 (max). However, for some measures the max score are R2 (A1, A5, C2), R3 (A3, C1) or R4 (B1, B2, B3). For each question, the user will choose an answer according to the possibilities (table 1). Based on the answer one score will be assigned. The final score will be based in the weighted evaluation of each set: connection, Data and Environment and User Satisfaction.

The weight of the measure (a percentage value) was defined taking into account the importance of each environment attribute for the ICU. The calculation of each metric is equal to (for all the set):

$$\sum_{k=0}^{n} \frac{K_\chi \, x \, R_\chi}{M_\chi}$$ Where,

- n: is the number of metrics in the group;
- K: is the weight associated to this measure;
- R: stands for the value of R score for the question chosen by user (e.g. R2 → 2);
- M: is the maximum of the score (K x Max R Value to this measure).
- *x*: corresponds to the question id.

Individually, the metrics are defined by:

Connection $$\chi = \frac{0{,}25A_1 + 0{,}1A_2 + 0{,}3A_3 + 0{,}15A_4 + 0{,}2A_5}{3.05} \quad (1)$$

Data $$\alpha = \frac{0{,}4B_1 + 0{,}3B_2 + 0{,}3B_3}{4} \quad (2)$$

Environment /User Satisfaction $$\beta = \frac{0{,}2X_1 + 0{,}3X_2 + 0{,}2X_3 + 0{,}3X_4}{7} \quad (3)$$

Global Evaluation Environment $$\Omega = \frac{0{,}3\chi + 0{,}4\alpha + 0{,}3\beta}{3} \quad (4)$$

According to the results obtained we can make some modifications or improve some aspects. Table 2 establishes the significance for each metric (1-4) in terms of a classification value ranging from Very Bad to Very Good. These percentages were agreed by the ICU and Information System professionals.

Table 2. Results Evaluation

Metric	Very Bad	Bad	Acceptable	Good	Very Good
1	< = 70%	< = 75%	< = 85%	< = 90%	> 90%
2	< = 75%	< = 85%	< = 90%	< = 99%	= 100%
3	< = 75%	< = 80%	< = 85%	< = 90%	> 90%
4	< = 80%	< = 85%	< = 90%	< = 95%	> 95%

6 Discussion

The features defined and evaluated in this work made possible to transform the system in order to be more secure, robust, easily accessible and intelligent. Is expected the system will improve the patient outcome in the future due to some new facilities like the data availability in online, real-time and in electronic format. With the ICU pervasive access recast, is possible to accede to knowledge portions that can support the decision making process, anytime, anywhere. Beyond the performance of INTCare, the evaluation of the success of the proposed environment depends on the results obtained after a sample of 100 surveys answers that will be done to all people that directly interacted with this new ICU environment and can answer (patient, doctors, nurses, other professionals). Based on the results obtained for each category and according to table 2 we will decide on what to do in the future. The results also can give us indications about if the new environment is or not prepared to implement a remote IDSS like is INTCare.

7 Conclusion

The right technologies in a smart environment can get some important objective: “help health care professionals to manage their tasks while increasing the quality of patient care” [8]. Like we can prove, is possible create a Pervasive and Intelligent Critical Health Care Environment for data acquisition and data consult with the max security and reliability for the ICU, their professionals, patients and applications. Almost all tasks can be intelligent and performed autonomous and in real-time.

The proposed environment allows for a total availability of data in electronic format wherever we need at the time that we want. However there are some operations that need to be performed manually like is the mode how data is validated. We can change the mode of data is validated. The data can be pre-validated automatically but the final verification has to be done by ICU professionals. We can improve the form how data is validated, but this process always needs to be human. Nothing can fail because patients’ lives are at risk. The impact of this on the society will be big, because the doctors can see the patient condition and treat him remotely. New systems have to be created and others need to be modified, because this environment will allow pervasive computing and new features can be added to the actual systems. The principal difference between this model and the previous is in the form of the data is collected, available and how it can be accessed. With the implementation of new environment and the guarantee of the success of operations at a distance, some new treatments can be performed and some lives can be saved.

8 Future Work

Now we are analysing the new environment and arrange some meetings with the objective to develop a Risk List and a contingency plan. The objective is to define actions that can avoid problems if something fails on the system. In the future we hope to have the entire ICU adapted to a pervasive and intelligent approach. The prevision and decision models will be improved and prepared to the pervasive environment.

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Grid Data Mining for Outcome Prediction in Intensive Care Medicine

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Abstract. This paper introduces a distributed data mining approach suited to grid computing environments based on a supervised learning classifier system. Specific Classifier and Majority Voting methods for Distributed Data Mining (DDM) are explored and compared with the Centralized Data Mining (CDM) approach. Experimental tests were conducted considering a real world data set from the intensive care medicine in order to predict the outcome of the patients. The results demonstrate that the performance of the DDM methods are better than the CDM method.

Keywords: Intensive Care Medicine, Outcome Prediction, Grid Data Mining, Distributed Data Mining, Centralized Data Mining.

1 Introduction

Recently, there is a significant progress in the research related to distributed data mining. Digital data stored in the distributed environments is doubling within a few years. More advanced and feasible distributed data mining algorithms and strategies are required in the current fast growing environment.

Learning Classifier System (LCS) is a concept formally introduced by John Holland as a genetic based machine learning algorithm [1]. Manuel Santos [2] developed the DICE system, a parallel and distributed architecture for LCS. In his work he attempted to parallelize the genetic algorithm and LCS message operations to increase system's performance. A. Giani, Dorigo and Bersini also did significant re attained in the experimental work research in the area of parallel LCS [3]. Their implementation also tried to increase the performance of the system. All implementations of parallel LCS consider a single data and generate a single model. Supervised Classifier System (UCS) is a LCS suitable for a supervised learning scheme.

This work is part of two major projects – the Gridclass project – whose main goal is to implement the UCS in a grid environment and – the INTCare project – whose main goal is to implement an intelligent decision support system for Intensive Care Units where the data distribution among distinct sites is an important issue. Gridclass system does not paralyze any part of the UCS. Various instances of the UCS are executed in different distributed sites with different set of data. All the experimental work was done using the Grid gain platform a java based distributed computing middleware [4].

M.M. Cruz-Cunha et al. (Eds.): CENTERIS 2011, Part III, CCIS 221, pp. 244–253, 2011.

The key objective of this work is to construct a global data mining model from different local models of the grid and compare Distributed Data Mining (DDM) and Centralized Data Mining (CDM) methods. Grid computing architecture is considered the best distributed framework for solving the distributed data mining task [5, 6]. Each node of the grid environment executes different instances of UCS and sends the local data mining models to the central site for developing a global model. This paper introduces two different methods for merging local models from each distributed sites: Specific Classifier Method (SCM) and Majority Voting Method (MVM).

The Intensive Medicine is a specific environment where the patients normally are in weak conditions. The decisions are normally conditioned by some stress or by a necessity of quickly response. For the doctors is very difficult to take decisions in this conditions especially when they don't have the required clinical data about the patients. INTCare [7, 8] allows for the outcome prediction in Intensive Care Units. In order to meet this objective, a platform was developed that allows for the clinical data collecting in real-time and in electronic format. This data will be used in a distributed data mining approach suited to grid computing environments based on a supervised learning classifier system.

The remaining sections of this paper are organized as follows: Section 2 gives the background details of the intensive care unit data, section 3 describes the way of data acquisition from ICU and section 4 explains the global model construction methods such as specific classifier method and majority voting method. Section 5 shows the experimental set up and the results obtained for DDM and CDM. Section 6 discusses the performance of DDM vs. CDM. Further section 6 shows some related works and final section presents main conclusions.

2 Background

2.1 Intensive Care Units

The Intensive Care Units (ICU) are the place where the knowledge and treatments associated to Intensive Medicine is applied. The main purposes of ICU are diagnose, monitor and treat patients with serious illnesses and recover them for their health and quality of life prior [9]. ICUs are concerned with these patients, and focus their efforts on the resuscitation of patients who are terminally ill or in treating patients who are vulnerable to an organic dysfunction, benefiting from the preventive care for each system dysfunction according to the principles of restoration to normal physiology [10], maintaining a serious and continuous monitoring of the patient. In the ICUs are used as decision support systems the disease severity index and prediction models, to predict the risk of in-hospital mortality through a set of prognostic variables that uses the predictive index of disease severity [11]. The models predict the mortality risk for a number of patients with a certain degree of physiological dysfunction. The most famous outcome prediction index is SAPS that is based on the worst results recorded in the first 24 hours after admission [12]. The systems that use this type of indices usually select the patient, evaluate and record the predictor variables, calculate the severity index and return the rate of mortality.

3 Data Acquisition in ICU

3.1 KDD Process in ICU

In order to obtain the maximum number of electronic data we developed an Electronic Nursing Record (ENR) to integrate a high number of hospital data sources like Electronic Health Process (EHR) and lab results. This approach allows for data acquisition, data monitoring and data validation, electronically, in an online and real-time mode. After collecting the data will be prepared and transformed to be used in a distributed data mining approach suited to grid computing. The Fig. 1 shows the data sources and the Knowledge Discovery in Database (KDD) process followed in the ICU.

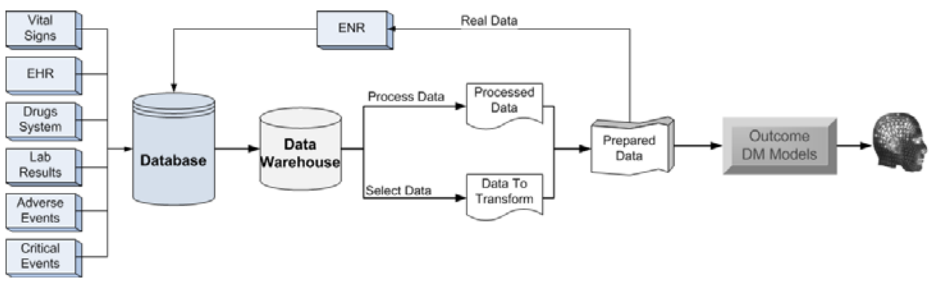

Fig. 1. ICU Knowledge Discovery in Database Process

3.2 Data Set Description

The data used in this approach were collected in real-time and is related with patient who had an entire stay with a full monitoring in ICU in the firsts five days. This data correspond to three months and thirty two patients. The input variables consist of: Admission data; Critical Events (CE); SOFA; and Accumulated Critical Events (ACE). The admission data (i.e. age, admission type and admission from) and Critical Events (CE), derived from four physiologic variables Blood pressure (BP), heart rate (HR) and oxygen saturation (SPo2) that were collected by the bedside monitors and urine output (UR) [13] . The Table 1 presents the values that are in the dataset and are obtained at the patient admission and after patient discharge.

For each variable (VAR): BP, HR, SPo2 and HR were calculated the AEC, EC and a set of ratios. The Table 2 shows the descriptions of each ratio and the possible values. CE was defined by a panel of experts [14]. If a physiological parameter is out of its normal range [15] for more than 10 minutes or the result is lower than the minimum acceptable, it is considered a CE. In consequence of CE we have the Accumulated Critical Events (ACE) that was derived as a new variable and is an hourly sum of CE of one patient during its staying. The score used in this data set was SOFA, which can quantify the level of failure (0-4) to each organ system (neurologic, cardiovascular, hepatic, renal, respiratory, coagulation). In this case, we transformed the data and considered 0 to normal values and 1 if an organ failure happened.

Table 1. Possible values of patient admission data

Variable	Description	Range
Hour	relating to 5 days of stay	[1-120]
Age	The age of patient admitted in ICU	1 - [18; 46]; 2- [47; 65]; 3 - [66; 75]; 4 - >= 76
Admission Type	The type of admission	{Urgent (U); Programmed (P)};
Admission From	Admission origin of the patient	1 - Surgery block, 2 - Recovery room, 3 - Emergency room, 4 - Nursing room, 5 - Other ICU, 6 - Other hospital, 7 - Other sources
Outcome	Patient final discharge	{Survivor (0); Deceased (1)}

Table 2. Possible values of events, ratios, and scores

Variable	Description	Range
EC	Number of critical events of each VAR occurred per hour	[0; + ∞]
AEC	Number of accumulated critical events of each VAR occurred	[0; + ∞]
ec_ac_var / EC_max	Number of accumulated critical events of each VAR occurred / Maximum number of critical events possible in an hour	[0; 1]
ec_ac_var / Horas	Number of accumulated critical events of VAR occurred / Hours of stay	[0; 1]
tot_ec_ac	Number of total critical events accumulated of all 4 variables	[0; + ∞]
tot_ec_ac / ec_max	Number of total critical events accumulated of all 4 variables / Maximum number of critical events possible in an hour of all var	[0; 1]
tot_ec_ac / Horas	Number of total critical events accumulated of all 4 variables / Hours of stay	[0; 1]
sofa_organ	SOFA value for each organ system	Failure (1) Normal (0)

Incorrect values were detected and corrected by ignoring values considered absurd by the medical experts. The resulting data of this prepared data process were used by Data Mining.

4 Global Model Construction

Gridclass uses the UCS for data mining proposes. Two levels of data mining models are generated in the Gridclass system. The first level is related to the models induced in each distributed sites and the second level corresponds to the model generated in the central site. The first data mining models are known as local models. The second level is known as global model and is generated from all the local models in the first level. The global model represents all the data in the distributed environment.

During the training process, Gridclass system generates data mining models based on the training data and a predefined set of classifiers [16]. If a predefined set of classifiers is provided, then the system can perform incremental learning. The incremental learning process improves the performance therefore the system can provide a more generalized learning model. If a predefined set of classifiers is not provided, then the system generates the data mining models only from training data. Data mining models are maintained by a genetic algorithm and covering operations in UCS system [17, 18, 19].

There are many challenges for constructing a global model, because wrong combination of the classifiers gathered from the local models, will affect negatively the performance of global model. The main difficulty is to derive the significance of each classifier and predict their values in the global model. All training data are completely independent even though there should be many similar classifiers with different sets of parameter values (benefits). Therefore the parameter evaluation of the classifiers in the global model is important.

Subsequent sections present two solutions that are suitable for constructing the global model.

4.1 Specific Classifier Method (SCM)

Specific Classifier Method (SCM) only preserves discrete classifiers in the global model [20]. SCM induce the global model without repeating similar classifiers and simultaneously keeping all the benefits of the local classifiers.

In SCM the initial process is to collect all the classifiers from the distributed sites and store them in a central location. The collected classifiers have to be evaluated based on the criteria of SCM and those classifiers that are eligible to be integrated the global model will be stored in the global model. While classifiers are evaluated, each classifier needs to be matched with all other classifiers in the collected local model. When one classifier finds another similar classifier in the collected local models then that classifier updates its parameters with parameters of matched classifier. Finally, the induced global model will be tested using a data set that was generated from the global data set.

4.2 Majority Voting Method (MVM)

Majority Voting Method (MVM) is another strategy for constructing the global model from distributed local models. The goal of the MVM is to eradicate weak classifiers from the global model and construct a strong model in the central system (global model). Initially, MVM gathers all local models and stores them in the central system, then goes on to find all discrete classifiers from the accumulated local models as SCM. Later, the system calculates a threshold value (*cut_ off_ threshold*) from the collected classifiers and uses it to benchmark the classifiers in the population [20]. If the accuracy of a classifier is greater than the *cut_ off_ threshold* value then that classifier will be stored in the global model.

5 Experimental Work

Experimental work intents to compare the performance of DDM and CDM therefore different sizes of iteration, population size and number of nodes were considered in the distributed sites. ICU data set has 3570 records of data and each record has 31 fields and each field has different ranges of the values. ICU data was divided for training and testing, i.e. randomly selected 70% of original data was considered as centralized training data and randomly selected 30% of original data was considered as centralized testing data. For the DDM training and testing data was made from the centralized training and centralized testing datasets. Based on the number of nodes in the distributed site centralized training and centralized testing data was equally divided. Centralized training dataset contains 2380 records and centralized testing dataset 1190. Two set of nodes were considered (Ten and twenty) in the distributed site therefore for 10 nodes 238 records of data in each training dataset and 119 records of data in each testing dataset. For the 20 nodes tests, 119 records of data were considered in each training dataset and 59 records of in each testing dataset. Similarly, considerable size of population and number of iterations of the CDM, population size and number of iterations were divided according to the number of nodes in the DDM. Three sets of iterations were considered for CDM (100000, 200000 and 300000) and four set of population sizes were selected for CDM (500, 1000, 2000 and 4000). For the ten nodes experiments in the DDM, were considered 10000, 20000 and 30000 iterations, and for the populations sizes 50, 100, 200 and 400 classifiers. For the twenty nodes, were considered 5000, 10000 and 15000 iterations and 25, 50, 100 and 200 classifiers. To compare the performance of each approach, we considered the accuracies (the average of 10 runs and the standard deviation). The configuration parameters used in the UCS are: *ProbabilityOfClassZero* = 0.5, *V* = 20, *GaThreshold* = 25, *MutationProb* = 0.05, *CrossoverProb* = 0.8, *InexperienceThreshold* = 20, *InexperiencePenalty* = 0.01, *CoveringProbability* = 0.33, *ThetaSub* = 20, *ThetaSubAccuracyMinimum* = 0.99, *ThetaDel* =20, *ThetaDelFra* = 0.10.

5.1 DDM Experiments

Table 3 shows the global model testing accuracies attained for the SCM and MVM strategies. Based on the testing accuracies, it is difficult to say which the best method for constructing the global model. But based on the global population size MVM is the best because the global population size of the MVM is always smaller than the global population size of the SCM. Testing accuracies increase in proportion to the population size as expected, for example, almost 93% of accuracy is achieved with global population size of 4000. Higher population sizes were not considered in order to avoid over fitting phenomena.

5.2 CDM Experiments

Unexpectedly, the testing accuracies of the CDM are smaller than the testing accuracies of DDM. The testing accuracies of the CDM also show the impact of the population size because the testing accuracies are increasing proportionally to the population size.

Table 3. Testing accuracies of global models generated using SCM and MVM

Number of Nodes	Iterations	Local Population Size	Accuracy		Global Population Size	
			SCM	MVM	SCM	MVM
10	10,000	50	0.716 ± 0.0110	0.7132 ± 0.01252	485.8 ± 4.87	381.3 ± 10.187
10	10,000	100	0.7987 ± 0.01586	0.7987 ± 0.0175	955 ± 5.35	655.7 ± 9.2141
10	10,000	200	0.8784 ± 0.01715	0.876 ± 0.01511	1884.8 ± 12.23	1070.8 ± 20.48
10	10,000	400	0.925 ± 0.009	0.92606 ± 0.0088	3730.9 ± 17.615	1710.7 ± 33.40
10	20,000	50	0.7116 ± 0.0203	0.723 ± 0.0318	486.4 ± 3.687	383.2 ± 9.635
10	20,000	100	0.80 ± 0.0159	0.807 ± 0.0217	958.8 ± 7.08	648.2 ± 11.698
10	20,000	200	0.8794 ± 0.060	0.8722 ± 0.01589	1885 ± 11.72	1067.5 ± 21.36
10	20,000	400	0.925 ± 0.0099	0.9229 ± 0.0123	3724 ± 12.18	1713 ± 42.62
10	30.000	50	0.712 ± 0.018	0.7188 ± 0.0151	484 ± 2.366	382.5 ± 12.020
10	30,000	100	0.807 ± 0.0173	0.8024 ± 0.0167	958.7 ± 4.80	654.8 ± 10.695
10	30.000	200	0.875 ± 0.019	0.8723 ± 0.0179	1890.2 ± 9.96	1063. ± 31.287
10	30,000	400	0.9244 ± 0.0085	0.925 ± 0.01153	3720.1 ± 20.82	1705.5 ± 24.24
20	5,000	25	0.7203 ± 0.0192	0.7345 ± 0.0232	488.2 ± 3.119	394.1 ± 6.789
20	5,000	50	0.8028 ± 0.0176	0.797 ± 0.0177	959.1 ± 6.55	676.1 ± 17.47
20	5,000	100	0.879 ± 0.0186	0.8781 ± 0.01084	1890 ± 11.2570	1111.9 ± 28.68
20	5,000	200	0.932 ± 0.0130	0.927 ± 0.00674	3733 ± 14.2126	1779.7 ± 31.16
20	10,000	25	0.72 ± 0.018	0.721 ± 0.0158	486 ± 4.13	391.7 ± 6.412
20	10,000	50	0.805 ± 0.0192	0.8061 ± 0.0197	962.6 ± 4.501	669.3 ± 16.97
20	10,000	100	0.8824 ± 0.0167	0.884 ± 0.0151	1892 ± 9.04	1101.8 ± 16.87
20	10,000	200	0.9298 ± 0.0153	0.9369 ± 0.0118	3729.9 ± 13.194	1757.3 ± 33.50
20	15,000	25	0.7197 ± 0.0965	0.7158 ± 0.0212	486.6 ± 4.5509	389.6 ± 7.29
20	15,000	50	0.8091 ± 0.0129	0.8054 ± 0.0134	961.6 ± 7.381	673.2 ± 38.473
20	15,000	100	0.8695 ± 0.0135	0.8699 ± 0.0132	1886 ± 10.286	1110.7 ± 10.69
20	15,000	200	0.9325 ± 0.00977	0.9325 ± 0.01022	3738.8 ± 20.339	1777.6 ± 019.18

Table 4. Testing accuracies for the CDM method

Iteration	Population Size	Accuracy
100,000	500	0.56232 ± .17046
100,000	1000	0.6035 ± 0.182586
100,000	2000	0.6585 ± 0.1992
100,000	4000	0.7086 ± 0.2138
200,000	500	0.565 ± 0.170825
200,000	1000	0.5974 ± 0.1808
200,000	2000	0.64885 ± 0.1962
200,000	4000	0.7114 ± 0.2146
300,000	500	0.5585 ± 0.1689
300,000	1000	0.5996 ± 0.1814
300,000	2000	0.6507 ± 0.1965
300,000	4000	0.7156 ± 0.216

6 Discussion

The main goal of this work is to induce global data mining models and compare the performance of CDM versus the DDM methods in a real world setting. The two strategies described above were able to construct the global model from the distributed local models. The global model in the CDM method is obviously representing the overall problem (dataset) in the distributed site because that model is generated from global data without any intervention. Global model of the DDM and learning model of the CDM were tested with the same data. Though table 1 and 2 show that DDM have best accuracies than CDM. For example, for 500 global population size of the DDM has around 71% of testing accuracy but the testing accuracy for 500 population size of the CDM is about 55%. For 4000 global population size the DDM reached around 93% of testing accuracy but the testing accuracy for the 500 population size of the CDM is only about 71%. Unexpectedly the DDM tests exceeded the CDM tests in terms of accuracy what means the SCM and MVM methods increased the efficiency of UCS learning components.

7 Conclusions and Future Work

This paper presented the performance of CDM and DDM approaches using ICU real data in order to predict the outcome of critical care patients. The experimental results clearly show that the performance of the DDM is better than the performance of CDM. The DDM strategies of SCM and MVM achieved similar testing accuracies but the global population size of MVM is smaller than the global population size of the SCM. The results are very important in areas were distributed data should be considered without discharging the local models induction as is the ICU.

Further work will include more methods to construct the global models from the distributed local learning models.

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DICOM and Clinical Data Mining in a Small Hospital PACS: A Pilot Study

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Abstract. Technological developments in the medical imaging acquisition and storage process have triggered the use of Picture Archiving and Communication Systems (PACS) with gradually larger archives. This paper aims to exploit advantages of using a DICOM Data Mining Tool in a hospital PACS. The results showed the tool reliability and performance to obtain and index clinical data, as well as the possibility of conducting flexible research on DICOM data fields, providing means for continuous improved practices at the Radiology Departments.

Keywords: PACS, DICOM Data Mining, Radiology Continuous Quality Improvement.

1 Introduction

Technological developments associated with the radiology practice are changing the way medical images and associated data are produced and handled. The gradual transition of radiology departments to fully digital environments, in which all acquired image data are available in digital format, promoted the adoption of new workflows that integrate new technologies for image acquisition, process and distribution [1]. Furthermore it has modified the way as different healthcare professionals interact with the medical image and related data, particularly after the adoption of the Picture Archiving and Communication Systems (PACS) [2, 3] in daily practice, including research and teaching activities [4-6] .

Technological developments, namely the Computed Radiology (CR) technology, have promoted a workflow change in the radiology department [1, 3] making possible to have the medical image in digital format. The intense investigation on technologies related to radiation detectors for medical imaging has been leading to the adoption of flat detectors (flat panels) for the radiographic images acquisition [7] and led to the emergence of a new medical imaging modality: the Digital Radiology (DR). Advances in digital technology allowed the development of full digital X-ray detectors that are currently available for projection radiography. CR and DR are digital technologies widely spread in healthcare institutions nowadays [7].

M.M. Cruz-Cunha et al. (Eds.): CENTERIS 2011, Part III, CCIS 221, pp. 254–263, 2011.

Other Medical Imaging Modalities such as Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) are digital modalities since the beginning and, therefore, the main difficulties when handling those images and studies are related to the integration of data produced by different manufacturers. Due to this the Digital Imaging and Communication in Medicine (DICOM) standard assume a key role in the integration process.

The standard defines a DICOM Information Model (DIM) that aims to represent the characteristics or attributes of real world objects logically grouped into different modules [8]. The information elements are organized as Information Modules (IM), Information Entities (IE), and IOD (Information Object Definition). They are structures hierarchically linked, where one or more IM creates an IE and a set of IE's forms an IOD. Each IE contains instances for a specific process to which they belong (e.g. image acquisition) or a real world entity (e.g. the Patient, Image, or Equipment)[9]. The DICOM standard specifies the instances that are part of a specific IOD.

The data associated with each of the modules is characterized by a unique identifier called tag and a value field or attribute. The tag consists of two numbers: Group and Element. The first number of the tag identifies the group number, e.g. the "0010" group includes information from the patient (Patient Group), and the "0018" group includes information on image acquisition (Acquisition Group). The second tag number identifies the element number. For example, the number "0020" represents the "PatientId" and the number "1400" identifies the "AcquisitionDevice ProcessingDescription" that is associated with the radiograph projection from which a CR image is obtained.

Access to medical images and related data by different health professionals, but also by equipment manufacturers, can result in the adoption of better professional practices and promote the development of new information resources and work methods.

When a radiology study is performed, the acquired images are sent to the PACS archive server and then distributed to predetermined workstations. Traditionally, there are two forms of PACS images distribution [10]:

- Using the DICOM Storage service communications (Store-and Forward) in which the images are initially stored in the PACS server and then distributed to the workstations;

- Using the DICOM Query/Retrieval service, where it is necessary to query and access images from the visualization workstation.

However, in traditional PACS, users are always dependent on the availability of a limited set of data that can be surveyed with standardized queries with low flexibility [11, 12].

In order to overcome access limitations to PACS data, some new applications have emerged, allowing us to conduct different queries to complement those available in traditional PACS [12-14], but none of them are based on open source software.

The use of DICOM Data Mining tools has been a valuable asset to analyze the information stored in the DICOM file. If much of the information currently associated with the image acquisition is stored in the Radiological Information System (RIS), in medical reports form, there are other innumerous data stored in the DICOM file object.

Actually, some data stored in the DICOM file is not searchable using traditional PACS database. However, it may represent an important source of information for continuous professional practice improvement [14, 15], namely when auditing the DICOM metadata stored in the PACS[16] or in quality assurance software utilization scope and radiation exposure monitoring [13, 14, 17-19].

One open source alternative solution that allows the realization of flexible queries on DICOM metadata is the Dicoogle [11, 20]. This software, installed on a personal computer, allows the query and index of DICOM metadata stored locally or in the medical imaging archive.

The Dicoogle makes two types of data indexing: a hierarchical content indexing of the DICOM metadata (patient, study, series, image) and a text content indexing (free text query) [11]. On the other hand, Dicoogle allows to suit different queries according with user profile, using the DICOM attribute value that the user want to query. It also can analyze DICOM attributes values pre-established by the user and export the data in Excel format, making possible the indexed data post-processing (e.g. perform quantitative analysis over the retrieved data).

The queries can be performed over any DICOM attribute and one single query search can include one or more attribute fields. For instance, to search CR modality studies with the text “BREAST” in the “BodyPartExamined” attribute field, the following query should be used: [Modality:CR AND BodyPartExamined:BREAST].

This paper aims to show some of the advantages of using Dicoogle as a DICOM Data Mining Tool in a small hospital PACS. Another objective is to assess whether the information obtained with Dicoogle may provide means for continuous improved practices at the Radiology Departments.

2 Materials and Methods

In the present work we carried out a retrospective study on DICOM Metadata stored in a small hospital PACS. Proper authorizations to the Hospital Board of Directors and to the Ethics Commission were requested making sure that confidentiality of the collected data was by all means guaranteed.

The PACS archive data indexing was made using Dicoogle. This application was installed on a personal computer with Windows XP OS and with an Intel Core 2 Duo P8600 processor with 2.40 GHz speed and a 2.85 GB RAM. The server connection was made through Ethernet and data access was done using a share folder on the PACS archive, with read-only permissions. The data access was subject to user validation with username and password and was collected during afternoon and evening hours, when the number of accesses to the PACS server is smaller.

A CR query was made ([Modality:CR]) in order to characterize the DICOM file metadata, particularly those related to the CR modality and identify those attributes that could demonstrate the performance and Dicoogle potential use in a clinical setting. The data analysis was performed according to two approaches:

- The patient oriented approach. The data analysis was made from the clinical and patient point of view. In this approach, the attribute "PatientID” was used in the search query, as well other associated data, in order to get the history of examinations made by a given patient. With results obtained, we tried to identify clinical features that may represent areas for practice improvement.

- The study oriented approach. The data analysis was made over a particular type of radiographic study: the mammography. The query structure selected was based on the "StudyDescription" attribute with the text value “BREAST” and aimed to know the number of studies and population x-ray exposure level in such studies.

3 Results

The indexing process occurs over a 250 GBytes of data volume and t lasted for 16.5 hours in smooth mode, resulting an indexed data folder with 581 MBytes. Along with the index data process were also created 96x96 matrix thumbnails of each image with the aim, whenever necessary, it is possible to confirm the relationship between the Metadata indexed and the image stored in PACS.

At the end of the indexation process, DICOM Metadata from 15682 patients with a total of 85757 images were collected. After indexing, the data extraction of all the studies took about 11 seconds.

The CR query ([Modality:"CR"]) was done in 5228 ms and resulted in a data sample from 13772 patients (7816 women, 5950 men and nine records with “PatientSex = O”), which corresponded to 41832 images.

With regard to the CR DICOM file metadata characterization it was found that some attributes are not used. This characterization also made possible to identify some DICOM attributes that were filled incorrectly like, for example, some "PatientID" and "ReferringPhysicianName” attributes (Table 1).

Table 1. Inconsistencies in the record of some DICOM attributes

Attribute	PatientID [0010,0020]	ReferringPhysicianName [0008,0090]	RequestingService [0032.1033]	RequestingPhysician [0032,1032]
1	1	-		
111111111	1	-		
Blank	36	5590	41825	41823
^^^^=^^^^=		2		
Exterior^^^^=^^^^=		2		
Consulta Externa^^^^=^^^^=		10		
MJC		8		8

Sample of 41831 files

The data relating to the "AcquisitionDeviceProcessingCode” (ADPC) and “AcquisitionDeviceProcessingDescription"(ADPD) attributes were exported in Excel format. These attributes characterize the radiographic projection that leads to the radiographic image. In a first analysis, we found that more than one ADPD attribute value to characterize the same radiographic projection were used. Some of these situations are related to Cervical Spine, Lumbar Spine and Mammography studies. Were also identified situations in which the same ADPC values was assigned for different ADPD attributes.

3.1 Dicoogle and the Patient-Oriented Approach

In a Patient-Oriented approach with clinical objective goals, DICOM metadata research can be made building diverse queries over different attributes. In this approach the query focus is the data associated with the "PatientID" attribute.

The use of different surveys, with different queries, allows to know the history of examinations made by a patient. Table 2 provides examples of “Mammography” and “Pelvis” data from two patients based on query [PatientID: 25798 AND Modality: CR AND StudyDescription: Mamografia] and [PatientID: 64385 AND Modality: CR AND StudyDescription: Bacia]. In both case, the query is based on the "PatientID" attribute value that we intend to study and analyze. In some cases is also important to have access to relevant data from other attributes such as the "SeriesInstanceUID", "AcquisitionDeviceProcessingDescription" or "AcquisitionDeviceProcessingCode.

Table 2. Study history based on the attribute "PatientId"

AcquisitionDevice	AcquisitionDevice	BodyPartExamine	Modality	PatientID	PatientName	ReferringPhysicianName	Sensitivity	StudyDate	StudyDescription	SeriesInstanceUID
349	C.C. DTA	BREAST	CR	25798	X^ROSA^ X		82	20081017	Mamografia	1.2.392.200036.9125.3.481999229166.64567009210.18605
349	C.C.ESQ	BREAST	CR	25798	X^ROSA^ X		90	20081017	Mamografia	1.2.392.200036.9125.3.481999229166.64567009210.18606
349	OBL DTA	BREAST	CR	25798	X^ROSA^ X		82	20081017	Mamografia	1.2.392.200036.9125.3.481999229166.64567009210.18607
349	OBL ESQ	BREAST	CR	25798	X^ROSA^ X		100	20081017	Mamografia	1.2.392.200036.9125.3.481999229166.64567009210.18608
349	C.C. DTA	BREAST	CR	25798	X^ROSA^ X	Exterior	53	20090821	Mamografia	1.2.392.200036.9125.3.481999229166.64594138711.18126
349	C.C.ESQ	BREAST	CR	25798	X^ROSA^ X	Exterior	50	20090821	Mamografia	1.2.392.200036.9125.3.481999229166.64594138711.18127
349	OBL DTA	BREAST	CR	25798	X^ROSA^ X	Exterior	68	20090821	Mamografia	1.2.392.200036.9125.3.481999229166.64594138711.18128
349	OBL ESQ	BREAST	CR	25798	X^ROSA^ X	Exterior	59	20090821	Mamografia	1.2.392.200036.9125.3.481999229166.64594138711.18129
349	C.C. DTA	BREAST	CR	25798	X^ROSA^ X	Exterior	53	20100412	Mamografia	1.2.392.200036.9125.3.481999229166.64614798813.72063
349	C.C.ESQ	BREAST	CR	25798	X^ROSA^ X	Exterior	59	20100412	Mamografia	1.2.392.200036.9125.3.481999229166.64614798813.72064
349	OBL DTA	BREAST	CR	25798	X^ROSA^ X	Exterior	54	20100412	Mamografia	1.2.392.200036.9125.3.481999229166.64614798814.72065
349	OBL ESQ	BREAST	CR	25798	X^ROSA^ X	Exterior	57	20100412	Mamografia	1.2.392.200036.9125.3.481999229166.64614798814.72066
500	BACIA	PELVIS	CR	64385	x^VERISSIMO^x	Serviço Internamento	76	20080419	Bacia	1.2.392.200036.9125.3.481999229166.64551114680.2485
500	BACIA	PELVIS	CR	64385	x^VERISSIMO^x	Serviço Internamento	183	20080424	Bacia	1.2.392.200036.9125.3.481999229166.64551568874.164128
508	ANCA, PRF	PELVIS	CR	64385	x^VERISSIMO^x	Serviço Internamento	241	20080424	Bacia	1.2.392.200036.9125.3.481999229166.64551569105.164130
500	BACIA	PELVIS	CR	64385	x^VERISSIMO^x	Consulta Externa	152	20080717	Bacia	1.2.392.200036.9125.3.481999229166.64558996002.1276217
518	ANCA,AXIA	PELVIS	CR	64385	x^VERISSIMO^x	Consulta Externa	215	20080717	Bacia	1.2.392.200036.9125.3.481999229166.64558996002.1276219
500	BACIA	PELVIS	CR	64385	x^VERISSIMO^x	Consulta Externa	156	20081016	Bacia	1.2.392.200036.9125.3.481999229166.64566940907.1656153
508	ANCA,FRN	PELVIS	CR	64385	x^VERISSIMO^x	Consulta Externa	340	20081016	Bacia	1.2.392.200036.9125.3.481999229166.64566940908.1656154
500	BACIA	PELVIS	CR	64385	x^VERISSIMO^x	Consulta Externa	163	20090311	Bacia	1.2.392.200036.9125.3.481999229166.64579887005.18727
508	ANCA, PRF	PELVIS	CR	64385	x^VERISSIMO^x	Consulta Externa	236	20090311	Bacia	1.2.392.200036.9125.3.481999229166.64579887393.18729
500	BACIA	PELVIS	CR	64385	x^VERISSIMO^x	Consulta Externa	171	20090721	Bacia	1.2.392.200036.9125.3.481999229166.64591481178.182829
518	ANCA,AXIA	PELVIS	CR	64385	x^VERISSIMO^x	Consulta Externa	357	20090721	Bacia	1.2.392.200036.9125.3.481999229166.64591481179.182831
500	BACIA	PELVIS	CR	64385	x^VERISSIMO^x	Consulta Externa	175	20100311	Bacia	1.2.392.200036.9125.3.481999229166.64612050890.368148
508	ANCA,FRN	PELVIS	CR	64385	x^VERISSIMO^x	Consulta Externa	365	20100311	Bacia	1.2.392.200036.9125.3.481999229166.64612050891.368149

The query arrangement of different DICOM attributes resulted in the possibility to characterize the history of recorded studies in the PACS archive. The examples of Table 2 provided some data on the performance of mammograms and pelvis from two patients based on query [PatientID:25798 AND Modality:CR AND StudyDescription:Mamografia] and [PatientID:64385 AND Modality:CR AND StudyDescription:Bacia]. In either case the search is based on the "PatientID" attribute and on the “StudyDescription” value that we intend to study and analyze. In some cases it is important to have access to relevant data from other attributes such as the "SeriesInstanceUID", "ADPD" and “ADPC”.

Looking to the Table 2, it is possible to identify some unusual cases. For instance, the Patient ID 64385 made seven “BACIA” (pelvis) and “ANCA” (hip joint) radiographs exam series ("SeriesInstanceUID" attribute) in two years. In this case, viewing the image series it was possible to understand the reason why. The patient had undergone a total hip prosthesis. With regard to patient with PatientId:25798, along with mammographic studies, the patient made breast ultrasound studies for nodule control.

With regard to factors related to radiation exposure, in CR modality the parameter that gives us an estimate exposure level is provided by the S Values stored in the "Sensitivity" attribute. From the Table 2 analysis we see that, in Mammographic studies [StudyDescription:Mamografia), there was a decrease of S Values between the 2008 studies and the 2009 and 2010 studies. In the “BACIA” and “ANCA” studies we found that the values do not vary significantly. It was also noted that it is not possible to know the provenance of mammographic studies performed in 2008.

3.2 Dicoogle and the Study Oriented Approach

The use of Dicoogle within the analysis of radiological studies was made based on "StudyDescription" attribute queries and other factors related to patient radiation exposure (e.g. number of projections taken, interval time and exposure level). As case study, we indexed and analyzed data from mammographic procedures. The ability to export DICOM Metadata in Excel format allows their statistical analysis presented in Table 3.

Table 3. Statistical analysis of radiation exposure levels from mammographic studies conducted between 2008 and 2010

StudyDescription (Mamografia)/Sensitivity (*S Value*)

Year	2008				2009				2010			
Incidence	C.C.DRT	C.C.ESQ.	OBL DRT	OBL ESQ	C.C.DTA	C.C.ESQ	OBL DTA	OBL ESQ	C.C.DTA	C.C.ESQ	OBL DTA	OBL ESQ
Average	94,1	94,1	97,5	98,1	64,9	66,9	77,4	67,5	64,0	66,1	67,0	65,5
Median	90,0	90,0	94,0	96,0	62,0	65,0	63,0	63,0	63,0	65,0	63,0	63,0
First quartile	82,0	84,0	84,0	86,5	57,0	59,0	57,0	59,0	57,0	59,0	59,0	57,0
Third quartile	100,0	100,0	105,0	105,0	70,0	73,0	74,0	73,0	70,0	71,0	73,0	70,0
Stand. Dev.	36,1	19,8	26,4	19,3	13,1	13,2	93,4	14,3	11,3	11,1	13,8	15,2
Nº of projections	352	347	359	358	246	238	249	241	288	291	293	293

Using the values provided by the "Sensitivity" attribute and, for the Right Cranio Caudal projection mammograms (C.C. DRT) performed in 2008, we analyzed the S Values dispersion (Fig. 1).

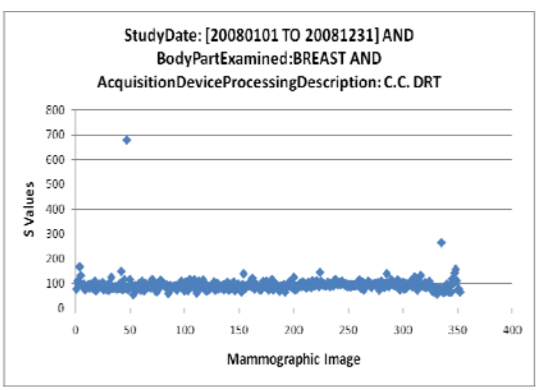

Fig. 1. S Values dispersion for the C.C. DRT mammograms performed in 2008

The possibility of doing queries based on textual values (e.g. identifying patients with S Values within a certain range of values) makes possible the identification of the image and associated procedure type (ADPD). For example, the image with S values above the sample average was possible to identify with the query StudyDate: [20080101 TO 20081231] AND BodyPartExamined:BREAST AND Acquisition DeviceProcessingDescription:C.C. DRT AND Sensitivity:FLOAT: [600.0 TO 700.0]. Based on the results, we can obtain the SeriesInstanceUID that identifies the image and their respective projection radiography ADPC and ADPD code (Table 4). By doing this, we can assess if the image quality is jeopardized by the x ray exposure level, since associated to a less x-ray exposure there is a lower signal/ noise ratio which can mask the existence of pathology.

Table 4. The SeriesInstanceUID that identifies the image with a lower S Value and their respective projection radiography ADPC and ADPD

ADPC	ADPD	BodyPartExamined	Modality	Sensitivity	SeriesInstanceUID	StudyDate	StudyDescription
349	C.C. DTA	BREAST	CR	679.0	1.2.392.200036.9125.3.481999229166.64548961956.16453	20080325	Mamografia

4 Discussion

The use of Dicoogle for the indexing and analysis of DICOM metadata has proved to be a valuable asset for the data characterization stored in the PACS archive, particularly in the CR modality context.

By allowing the construction of multiple views over data repository, in a flexible and quickly way, and with the possibility to export data for further statistical analysis, Dicoogle made possible to identify data and processes inconsistencies. This can contribute for the practices improvement of radiology departments.

The interpretation of data obtained with DICOM data mining tools, such as Dicoogle, must take into account issues related to professional reality that is specific to each healthcare unit. This should be taken into account namely when accessing the PACS archives that store large volumes of information, as is the case of CT or MRI.

The initial characterization of the DICOM metadata stored in the PACS archive was crucial, since it allowed us to exclude right from the beginning queries with unused attributes. Some of these data may be considered of interest to identify areas for the practices improvement of radiology departments. For example, if the attribute "OperatorName" is not provided, it will be difficult to implement individual plans for improvement. Moreover, other attributes such as "PatientAge" or "PatientBirhtDay" are not always used, which also happens with attributes like "Laterality" or those relating to the medical services identification and subscribers.

Some of the data incongruence identified, namely the existence of images without a "PatientID" (67 records) and images without "ReferringPhysicianName" (5576 records), "RequestingService” (41825 records) and" RequestingPhysician (41823 records), may be a disturbing factor for the proper information management stored on PACS archive. However, it is necessary to take into account that some of the inconsistencies may arise from trials procedures when installing the equipment.

With regard to image processing, the same ADPC attribute value can correspond to a different real ADPD. However, since for the same ADPC attribute value can match more than one ADPD attribute value, the query based on the ADPC attribute can bias the results. For example, if we want to know how many CC DRT mammographic projections were made, we should not use the ADPC "349" since this code is linked to other projections mammography ADPD (e.g. CC ESQ, OBL DRT, OBL ESQ).

Within the construction of queries based on a ranges of values, in more than one DICOM attribute, became evident the accuracy and validity of the extracted information, which enable the queries based on multiple attributes and to search data using default DICOM values selected by the user.

During the investigation it was possible to show the number of studies belonging to a patient as well as their frequency and level of radiation exposure that the patient was subject in each study.

However, it is necessary to be careful in interpreting the data since the same image can be acquired for different purposes, which may have implications in terms of image acquisition techniques. On the other hand, there are clinical situations involving the realization of control studies conducted in short time intervals, which does not reflect an example of bad practice.

The realization of a large number of images obtained in a short period of time also raises issues relating to radiation exposure. This is relevant for those making the studies, but should also be taken into account by the referring physician and the patient.

Within the mammographic studies, the S values statistical analysis showed that studies performed in 2009 and 2010 were performed with higher dose of exposure, since the higher the S Value the lower the radiation dose used for image acquisition [21] and it is also evident a lower standard deviation.

Another aspect to consider is that the differences between the number of images in different mammography examinations (characterized by the ADPD attributes C.C.DRT, C.C.ESQ, OBL ESQ and OBL DRT) are not synonymous with data incongruence's. This difference in values may be associated with factors related to clinical information or factors inherent to the patient (e.g. studies of patients who underwent mastectomy).

The use of Dicoogle in a clinical environment allows access to data that would otherwise be difficult to analyze and interpret. Like other software applications [4-6], the Dicoogle allows access to essential data for professional practice analysis. More than that, it also provide added value in the data monitoring and in the information audit process since it allows the possibility of conducting queries in a flexible and personalized way.

Aspects related to poor data recording mentioned by [16] also appear evident in the analyzed data, particularly regarding the entities that order and perform radiographic examinations.

The results obtained with the use of Dicoogle in clinical environment and presented in this paper do not represent the full potential of this DICOM Data Mining tool. In fact, the use of data relating only the mode of CR can be understood as a limitation of this study, but this approach was intended to be only one example of the use of a tool for DICOM Data Mining in a small hospital, fitting to the objectives outlined at the beginning of the work.

5 Conclusions

The use of DICOM Data Mining tools in a hospital environment can result in gathering important data for the professional practice improvement. These tools can also contribute to the PACS information audit and facilitate access to relevant clinical data within programs for quality continuous improvement.
Dicoogle allows access and further analysis of data that would otherwise be difficult to acquire and interpret.

The retrieved data obtained through Dicoogle, allowed the identification of factors that may contribute to a healthcare deficit. Although the results obtained reveals a low percentage of non-conformities, in the healthcare arena the goal is always the "zero errors" level.

The Dicoogle also has proven to be useful in collecting data related to patient studies together with other data queries that are not normally available in traditional PACS software modules.

The use of Dicoogle in larger PACS, , covering a broader set of imaging modalities that produce large data volumes, represents a challenge but also a wealth of possibilities that will be analyzed in future work.

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Preventing the Impact of Marital Dissolutions in Children by Regression Techniques

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Abstract. The process of marital dissolution is a crisis that affects both the couple and their offspring. Many studies have shown how children involved in a marital dissolution could present less adaptation abilities as well as less healthy live habits. The longer the process, the more serious become these problems. Therefore, to be able to take preventive actions would be quite useful towards minimizing the dissolution process impact. This paper aims at supporting the decision of doctors when deciding about a possible treatment to children involved in a dissolution process studying the extension of time that the dissolution procces spend.

Classical statistical techniques as well as latest machine learning algorithms will be applied in order to predict how long the dissolution might take and which parameters could be the most significant. The information used in this study comes from the Spanish government monitorization of the dissolutions during the last years.

1 Introduction

Diseases and health problems are not randomly distributed in society. Scientific research on public health field widely shows that social and demographic factors have enormous influence on population and people health [6]. A large number of studies prove that health inequalities derived from origin and social stratum explain mortality and morbidity excess more than the known specific risk factors for the most of diseases [7], [8].

Several medical and sociological researchs show that marital dissolution are a powerful psycho-social risk factor which can make high deteriorations on people involved health, both adult and children, as in physical as mental level (see [9], [10], [11], [12], [13], [14], [15]). The studies with vital trajectories show that the negative effects due to marital crisis and transitions on health are accumulated and extended for the rest of life [16].

There exists a lot of scientific evidences about the break of a couple is associated with a higher risk on the children of the couple showing alterations,

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disorders and loss in health (see [17]). Longitudinal studies demonstrate that worse initial situations, during childhood and youth, more severely limite the opportunities to achieve optimum levels on health. The adverse psycho-social circumstances, emphasizing the family breakdown, do exert a direct negative influence on the socio-economic situation, which is on the base of the explanation for every health inequality models.

Time duration of the legal process for marital dissolution behave as a worst forecast factor in terms of the magnitude, intensity and duration of the negative effects observed in the children health and welfare.

A way to prevent the negative effects on health is to reduce the duration of the process, understanding that higher time duration, higher the adverse effect is. We have studied how is time duration of the process related with other variables that the National Statistics Institute of Spain collect, for public statistic aims, with the objective to find a function that support medical decisions.

The results showed in this paper allow to forecast rather the duration time of the dissolution process will be either less or longer than six months. In section 2 the objectives of the research are established. Following, in section 3 the material and methods used are described and in section 4 the experimental results are exposed and briefly analyzed. Finally, in section 5 conclusions of the research are summarized.

2 Objectives

This paper is focused on forecasting the time duration of the marital dissolution processes. For this aim we will use two prediction models under two different points of view: the first one is made by discriminant analysis, as an appropriate statistical technique, and the other is carried out with RBF Neuronal Network, as a recently developed and powerful computational technique.

The output of the system could be incorporated in a decision support system in order to identify the possibility of going through a large dissolution process. If this is possible, preventive procedures could be taken in order to minimize the damage the people involved in the dissolution might suffer.

3 Material and Methods

For forecasting the dissolution process time duration, two methodologies have been carried out: the fist one applying discriminant analysis and the other one applying RBF Neuronal Network. Both have been developed using the data base provided by the National Statistic Institute of Spain that we describe in section below. Subsections following briefly describe the prediction methods and software required.

3.1 Data Base

To be agreed with the objectives of the research, we have developed forecast mechanism for the time duration of the marital dissolution process, based on certain information related to family socio-demographic characteristics. The database set used in the estimation and validation of the forecasting models is the microdata file about all the dissolution sentences passed on Spain during 2008. This data set, provided by the Judge Statistics Unit on the National Statistics Institute of Spain, collect all computed sentences by the General Council Judiciary between, January-1th and December-31th on 2008.

All the 81855 cases are described in the database set by 30 variables with a high level of enforceability. Valid data are between 95% and 100%. In the database homosexual marital dissolutions are excluded. For each pass, the variables computed are: Province and Autonomous Region; Birth Day, Month and Year for each spouse, Day, Month and Year for the marriage holding, of the lawsuit bring and of the sentence pass; the Plaintiff Spouse; Nationality and Previous Marital Status for each married couple; Previous Marital Separation; Number of under 18s children; Who pays Compensatory Damages; Who pays Maintenance; Who has under 18s children custody; and Judgement Declaration.

This database provides us any amount of socio-demographic information for families with a marital dissolution occurred in 2008. From these data information we have generated some new variables, removing the reference year effect, and we have used them for forecasting the time duration of the process. These variables are: Husband and Wife ages at marriage and the time between the marriage and the dissolution lawsuit. Therefore, we have taken into account the contentiousness generating a new variable. It has been possible because Judgement Declaration has the necessary information. Finally, we have removed from the independent variables data set the dates of the lawsuit bring and sentence pass. The first one is the dependent variable which we want to predict, and the later one gives, since we know that all sentences are passed in 2008, information about the process duration. This information might not be take because it is not available usually. After the transformations on the database, we have the following set of prediction variables:

Variable	Socio-demographic information related
V1	Province
V2	Number of under 18s children
V3	Husband Nationality
V4	Husband Previous Marital Status
V5	Wife Nationality
V6	Wife Previous Marital Status
V7	Judgement Declaration
V8	Plaintiff Spouse
V9	Previously Marital Separation
V10	Autonomous Region
V11	Time between Marriage and Dissolution lawsuit
V12	Husband age at marriage
V13	Wife age at marriage
V14	Contentiousness

The data set has been divided into two subsets: the named training data set and the named test data set. The purpose of this division is to make the prediction model using the first one and to check the models efficiency on the second data set. For this aim, we have randomly divide the 81855 cases into 46895 cases (57.29%) for training set and 34960 cases (42.71%) for test set.

3.2 Discriminant Analysis

Discriminant Analysis is a statistical technique developed by Fisher [1]. It is a multivariate statistic technique focused on verify if significant differences between groups exist, explain the differences and forecast the most probably group for new cases (see [2]). There must be a variables set, observed in these groups to explain, if the differences exist, how they are and which way they occur, giving us a systematic classification procedure for new observations. This Analysis looks for discriminant functions, calculated in a similar way that multiple linear regression equations. It consists in getting, from the independent variable set, some lineal functions $D_k = u_1 x_{1k} + u_2 x_{2k} + \ldots + u_d x_{dk}$ with $k = 1, \ldots, n$ with the power to classify another observations.

In the application of discriminant analysis, it has been used SPSS software, in the 15th version. This program has the advantages of intuition and easy to work with. The most important disadvantage consists in the fine depuration that it must be done on the data set before running the program. Furthermore, manipulate and insert modifications on the process are not simple.

3.3 RBFNN Description

A Radial Basis Function Neural Network (RBFNN) is a especial kind of Artificial Neural Networks which has an unique hidden layer of processing units, and each one of those, computes a Radial Basis Function. This kind of networks are very popular since they are able to approximate any function [21]. Given a designed RBFNN, the output is computed as a weighted sum of the outputs of the neurons:

$$\mathcal{F}\left(\boldsymbol{x}_k; C, R, \Omega\right) = \sum_{j=1}^{m} \phi(\boldsymbol{x}_k; \boldsymbol{c}_j, r_j) \cdot \Omega_j \tag{1}$$

where $C = \{\boldsymbol{c}_1, ..., \boldsymbol{c}_m\}$ is the set of RBF centers, $R = \{r_1, ..., r_m\}$ is the set of values for each RBF radius, $\Omega = \{\Omega_1, ..., \Omega_m\}$ is the set of weights and $\phi(\boldsymbol{x}_k; \boldsymbol{c}_j, r_j)$ represents an RBF. For regression and classification problems, due to its properties and good behaviour, the most commonly used RBF is the Gaussian function:

$$\phi(\boldsymbol{x}; \boldsymbol{c}_i, r_i) = \exp\left(\frac{-||\boldsymbol{c}_i - \boldsymbol{x}||^2}{r_i^2}\right) \ , i = 1, ..., m \tag{2}$$

Design of an RBFNN. As described above, there is a set of parameters that have to be initialized in order to obtain an RBFNN, these are: number of RBFs, their position in the solution space, their widths and the weights for the output layer. Although there are several methodologies to design RBFNN [18,20], the classical procedure consists of:

1. Initialize RBF centers $\boldsymbol{c}_j$
2. Initialize the radius r_j for each RBF
3. Calculate the optimum value for the weights Ω_j
4. Apply a local search algorithm

Once the centers are initialize, the widths are usually computed based on their position controlling the overlapping degree. Afterwards, the output weights can be calculated optimally by solving a linear equation system.

The first step of initialization is crucial in order to obtain good approximation results due to the large number of local minima. In order to overcome this problem, specific clustering algorithms have been developed [24,23,19]. In this paper we have selected the approach proposed in [19] due to its good results and possibility of obtain with the same algorithm the widths for the RBFs.

This algorithm defines a distortion function that has to be minimized in order to make an adequate placement of the centers:

$$\delta = \sum_{k=1}^{n} \sum_{i=1}^{m} D_{ik}^2 a_{ik}^l |Y_k^p| \tag{3}$$

where D_{ik} represents the Euclidean distance from a center c_i to an input vector $\boldsymbol{x}_k$, a_{ik} is the activation value that determines how important the input vector $\boldsymbol{x}_k$ is for the center $\boldsymbol{c}_i$, l is a parameter to control the degree of overlapping between the neurons, Y_k is the preprocessed output of the input vector $\boldsymbol{x}_k$, and p allows the influence of the output when initializing the centers to increase or decrease.

4 Experimental Results

This section will compare the regression techniques in order to see which one performs better in general and also analysing the specificity. The marital dissolutions were classified in two groups: less than 6 months and more than 6 months. The results obtained by the Discriminant Analysis are shown in Table 1 and the ones provided by the RBFNN are shown in Table 2. The continuous output of the RBFNN is shown in Fig. 1 where it is possible to see how is able to approximate reasonable well the marital dissolutions between the range of 100 to 300 days although the others, specially the largest and the smallest, is not able to perform an accurate approximation.

Both methods perform well, making a correct classification in most of the cases although the approximation of the number of days is not too accurate. Regarding the accuracy of the classification, it is possible to see how it more difficult to detect if a dissolution will last over 6 months. Nonetheless, both models obtain accuracies over the 60%, which is an acceptable result.

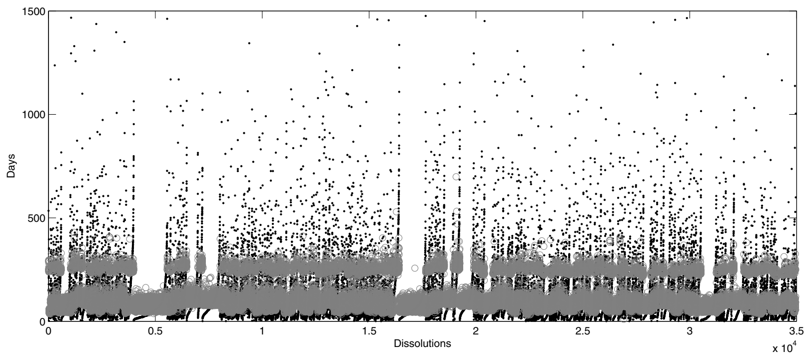

Fig. 1. Approximation of the RBFNN over the test data set. Black dots are the real output and grey circles are the output of the network.

Table 1. Classification Results for the Discriminant Analysis

Training	Total	Less than 6 months	More than 6 months
Correct classification	82,7%	87,96%	64.48%
Wrong classification	17,3%	12,14%	35.52%
Test	Total	Less than 6 months	More than 6 months
Correct classification	83%	87.94%	65.7%
Wrong classification	17%	12.06%	34.3%

Table 2. Classification Results for the RBFNN using X neurons

Training	Total	Less than 6 months	More than 6 months
Correct classification	82.65%	88.1%	64.4%
Wrong classification	17.35%	11.9%	35.6%
Test	Total	Less than 6 months	More than 6 months
Correct classification	82.9%	88.05%	65.6%
Wrong classification	17.1%	11.95%	34.4%

5 Conclusions

Marital dissolutions are a traumatic problem for all the people involved in them that directly affects their health. As the longer this process becomes, the more severe the damages are, it is useful to have a decision support system that, given a set of variables, is able to determine if the dissolution will last for a long time or not so preventive methods can be applied. This paper has presented two mathematical models that are able to asses about the duration of the dissolutions. Both approaches, the statistical and the machine learning, have performed similarly showing no significant differences regarding the accuracy of the results.

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Artificial Neural Networks in the Discrimination of Alzheimer's Disease

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Abstract. Alzheimer's disease (AD) is the most common cause of dementia, a general term for memory loss and other intellectual abilities. The Electroencephalogram (EEG) has been used as diagnosis tool for dementia over several decades. The main objective of this work was to develop an Artificial Neural Network (ANN) to classify EEG signals between AD patients and Control subjects. For this purpose two different methodologies and variations were used. The Short time Fourier transform (STFT) was applied to one of the methodologies and the Wavelet Transform (WT) was applied to the other methodology. The studied features of the EEG signals were the Relative Power in conventional EEG bands (delta, theta, alpha, beta and gamma) and their associated Spectral Ratios (r_1, r_2, r_3 and r_4). The best classification was performed by the ANN using the WT Biorthogonal 3.5 with AROC of 0.97, Sensitivity of 92.1%, Specificity of 90.8% and 91.5% of Accuracy.

Keywords: Alzheimer's Disease, Electroencephalogram, Artificial Neural Networks, Short Time Fourier Transform, Wavelet Transform.

1 Introduction

Alzheimer's disease is a chronic and progressive neurodegenerative disorder and it's the most common cause of dementia in the elderly [1]. In 2001, more than 24.3 millions of people with AD lived all over the world and according to estimates of Delphi in 2040 they will be 81.1 millions [1]. This progressive disease of brain can affect several cerebral areas charge by memory, thinking, planning and attention [2].

To reduce the damage suffered by the patient's brain an early diagnosis is necessary. For a several decades the EEG has been used as a diagnostic tool for dementia [3]. The EEG is a noninvasive technique that records the electromagnetic fields produced by brain activity with good temporal resolution [3]. EEG presents different frequency bands, such as delta (1-4 Hz), theta (4-8 Hz), alpha (8-13Hz), beta1 (13-19 Hz), beta2 (19-30 Hz) and gamma (30-40 Hz). AD seems to affect those different bands in frequency. The principal effect is known as the EEG "slowing". Several studies have shown that AD causes slow down on EEG signals [3] that means an increase of power in low frequencies (delta and theta band) and a decrease of power in higher frequencies (alpha and beta) [3]. This phenomenon so called "shift-to-the-left" appears in advanced and intermediate states of AD and can be seen notably in the peak occurring at alpha range [3].

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In this study we want to develop an ANN to discriminate EEG signals between AD patients and Control subjects. For this purpose we use two different methodologies and variation. The STFT is applied to one of the methodologies and the WT is applied to the other methodology. Ten spectral parameters are calculated: Relative Power (*RP*) at delta, theta, alpha, beta1, beta 2, gamma frequencies and spectral ratios (r_1, r_2, r_3 and r_4).

2 Materials

2.1 Selection of Patients and Controls / EEG Recording

Thirty four subjects participated in the study (14 Controls and 20 with a probable diagnostic of AD). All EEG recordings were performed in the "Hospital Universitario Pío de Río Hortega" (Valladolid, Spain). EEGs were recorded from the international system 10-20 of 19 loci using a digital electroencephalograph Xltek of Natus Medical Inc. Sample frequency was 200 Hz. Recordings were made with the subjects in a relaxed state and under the eyes-closed condition in order to minimize the percent of artifacts. All EEGs were visually inspected by a specialist to check artifacts. Afterwards, EEGs were organized in 5 seconds artifact-free epochs (1000 points). All recordings were digitally filtered with a band-pass filter between 1 Hz and 40 Hz.

2.2 Time-Frequency Representations

The first attempt to apply Fourier analysis to EEG signals dates back to 1932 [4]. FFT, since it was introduced in 1965, remains the spectral EEG signal processing most commonly used until today [4]. However FFT is not able to provide information both in time and frequency of signal characteristics. The spectral components do not reflect changes over time, which is a problem to analyzed non-stationary signals, such as EEG [5]. To solve this problem, STFT was introduced. It uses a constant time window, and this short time window of the original signal is transformed into the frequency domain. The window is then shifted to a new position and the transform is repeated within the all signal [5]. But, with STFT is difficult to obtain a high resolution in the time domain and in the frequency domain simultaneously. The information has limited in accuracy because of the STFT window width [5]. To solve this problem, a transform that is independent of scale was defined. This transform is known as WT that gives an excellent resolution for all frequency ranges, therefore being an optimal tool for data analysis when time and frequency resolution were critical [5]. We computed Power Spectral Density (*PSD*) functions that showed the strength of the variations of Power as a function of frequency [6]. The mean *PSD* were obtained per channel and subject from 1Hz to 40 Hz. *PSD* was estimated by two technics: from the autocorrelation function of STFT and with WT Spectrum technic. WT Spectrum was calculated at the decomposition level 7. The original time signal $x(t)$ was sampled at $F_s = 200$ Hz ($F_s = 1 / Ts$), resulting $x[n]$.We calculated the Discrete STFT from the signal $x[n]$.

$$X_w[m,k] = \sum_{n=0}^{L-1} x[n] \cdot w^*[n-m] \cdot e^{-j \cdot k \cdot \Omega_0 \cdot n}, \quad k = 0, \dots, L-1; m = 0, \dots, N_T - 1, \qquad (1)$$

where $\Omega_0 = 2 \cdot \pi/(\mathrm{L}-1)$ represented the fundamental frequency, k identified the frequency of the sinusoid associated with $X_w[m,k]$; N_T=N/L, where L was the STFT window length and N the number of samples. Thus, the discrete frequency could be identified as $\Omega = k\Omega_0$.Then we estimated the short-time autocorrelation as follow,

$$R_{xx}[m,u] = \begin{cases} \frac{1}{L} \cdot \sum_{n=0}^{L-u-1} x[n+m] \cdot w'[n] \cdot x[n+m+u] \cdot w'[u+m] & ,u \geq 0 \\ R_{xx,w}^{*}[-u] & ,u < 0 \end{cases} \tag{2}$$

and with it, we calculated *PSD* ($S_{x,w}[m,k]$) by the Discrete Fourier Time Series (DFTS) of short time autocorrelation,

$$S_{x,w}[m,k] = \frac{1}{L} \cdot DFTS\{R_{xx,w}[u]\} = \frac{1}{L} \cdot \sum_{u=0}^{2L-1} R_{xx,w}[u] \cdot e^{-j \cdot \Omega \cdot u} = \frac{1}{L} \sum_{u=0}^{2L-1} R_{xx,w}[u] \cdot e^{-j\frac{2 \cdot \pi \cdot k}{2 \cdot L-1}u}$$
$$,k = 0,\dots,2L-1;\; m = 0,\dots,N_T-1; \tag{3}$$

On the other hand, the *PSD* of Wavelet was obtained by extracting the Wavelet Packet coefficients corresponding to the terminal nodes. We defined Wavelet Packet Transform (WPT) function as [6],

$$X_{\varphi,\psi}[j,m,k] = \sum_{n=0}^{\frac{N}{2^{j-1}}} WP^{\varphi,\psi}[j,m,n] \cdot w_{j,m,k}[n]\,,\; w_{j,m,k}[n] = 2^{-\frac{j}{2}} \cdot w_m[2^{-j} \cdot n - k],$$
$$j = 1,\dots,J;\;\; m = 0,1,\dots,2^j-1;\; k = 1,\dots,2^{J-j}\,, \tag{4}$$

where $J = log_2(N)$, j represented the level of decomposition of the WPT, φ the scaling function, ψ the Wavelet function, k the translation parameter, *N* the samples and *WP* the Wavelet packet . To estimate the Wavelet Packet Spectrum we used the WPT periodogram based on the observations of length $N = 2^j - 1$.

$$S_{x,\varphi,\psi}[m,k] = \left[\sum_{j=1}^{J} X_{\varphi,\psi}[m,k]\right]^2; \qquad m = 0,1,\dots,2^j-1;\; k = 1,\dots,2^{J-j}\,; \tag{5}$$

To obtain the frequency spacing of Wavelet Spectrum of each level of decomposition we used the range $\left[\frac{F_s}{2^{j+1}}, \frac{F_s}{2^{j+1-1}}\right], j = 1,\dots,log_2(N)$. Summarizing, the absolute value of the coefficients was taken and the Wavelet coefficients were ordering by frequency. The Wavelet Spectrum was computed by Wavelet Biorthogonal (Bior) 3.5. The *PSD* was normalized (PSD_n) as below:

$$PSD_n{}^{(i)}[m,k] = \begin{cases} \frac{S_{x,w}[n]}{\sum_{n=k1}^{k2} S_{x,w}[n]} \\ \frac{S_{x,\varphi,\psi}[n]}{\sum_{n=k1}^{k2} S_{x,\varphi,\psi}[n]} \end{cases} \tag{6}$$

where $i = \{STFT, WT\}$, k_1 and k_2 represented the discrete cut-off frequencies and can be calculated as:

$$k_1 = \frac{f_1 \cdot K}{f_s} \;\; ; k_2 = \frac{f_2 \cdot K}{f_s} \tag{7}$$

where f_1 and f_2 were the continuous cut-off frequencies of digital-band filter 1 and 40 Hz. F_s were the sampling frequency and K (capital letter) represented the frequency bins [6].

The $PSD_n{}^{(i)}[m,k]$ of 5 seconds segments was averaged per segments of 5 seconds, per channel and subject, respectively as,

$$< PSD_n^{(i)}[k] > = \begin{cases} \frac{1}{G} \cdot \sum_{m=0}^{N_T-1} PSD_n^{(i=STFT)}[k] \\ \frac{1}{G} \cdot \sum_{m=0}^{2^j-1} PSD_n^{(i=WT)}[k] \end{cases} \quad (8)$$

where $i = \{STFT, WT\}$ and G the number of samples. The variable k is related with f by the relationship given by Equation (7).

$$< PSD_n^{(i)}(f) > = < PSD_n^{(i)} \left[\frac{k \cdot fs}{K}\right] > \quad (9)$$

2.3 Definition of Spectral Parameters

To characterize the spectral content of each EEG recording, STFT and WT were used and two kinds of parameters were determined.

First of all, the RP was calculated as the sum of the components of the PSD_n in the conventional frequency bands: delta (1-4 Hz), theta (4-8 Hz), alpha (8-13Hz), beta1 (13-19 Hz), beta2 (19-30 Hz) and gamma (30-40 Hz):

$$RP(delta)^{(i)} = \sum_{f=1Hz}^{4Hz} < PSD_n^{(i)}(f) > ; \quad (10)$$

$$RP(theta)^{(i)} = \sum_{f=4Hz}^{8Hz} < PSD_n^{(i)}(f) > ; \quad (11)$$

$$RP(alpha)^{(i)} = \sum_{f=8Hz}^{13Hz} < PSD_n^{(i)}(f) > ; \quad (12)$$

$$RP(beta1)^{(i)} = \sum_{f=13Hz}^{19Hz} < PSD_n^{(i)}(f) > ; \quad (13)$$

$$RP(beta2)^{(i)} = \sum_{f=19Hz}^{30Hz} < PSD_n^{(i)}(f) > ; \quad (14)$$

$$RP(gamma)^{(i)} = \sum_{f=30Hz}^{40Hz} < PSD_n^{(i)}(f) > ; \quad (15)$$

where $i = \{STFT, WT\}$.

We also computed four spectral ratios to summarize the deceleration of the EEG spectrum of AD patients [7].

$$r_1{}^{(i)} = \frac{RP(alpha)^{(i)}}{RP(theta)^{(i)}} ; \quad (16)$$

$$r_2{}^{(i)} = \frac{RP(alpha)^{(i)} + RP(beta1)^{(i)} + RP(beta2)^{(i)} + RP(gamma)^{(i)}}{RP(delta)^{(i)} + RP(theta)^{(i)}} \quad (17)$$

$$r_3{}^{(i)} = \frac{RP(beta1)^{(i)} + RP(beta2)^{(i)}}{RP(delta)^{(i)}} ; \quad (18)$$

$$r_4{}^{(i)} = \frac{RP(beta2)^{(i)}}{RP(delta)^{(i)}} \quad (19)$$

2.4 Statistical Analysis

The Principal component Analysis method (PCA) summarizes the information and detects correlations among the variables [8]. The method generates a new set of variables, called *principal components.* Each principal component is a linear combination of the original variables. The values of each principal component can be analyzed using statistical techniques like analysis of variance and regression analysis, among others, in order to remove the similar components that can lead to errors in the ANN [8].

We analyzed the Normality of the parameters distribution with Kolmogorov test and the homoscedasticity with Levene's test. The distribution of parameters does not meet the hypothesis of parametric tests. And so, we studied the differences between the groups by Kruskal-Wallis medians, which is a non-parametric-test. We present the p-values obtained by Kruskal-Wallis for the RP parameters and spectral ratios obtained by WT and STFT processing's per subject in Table 1.

The results of ANN classification were analyzed by Receiver Operating Characteristic (ROC) curves. This statistical method summarizes the performance of a two-class classifier across the range of possible thresholds [9]. It is a graphical representation of the trade-off between sensitivity and specificity. Sensitivity represents the percentage of patients correctly classified, specificity is the proportion of controls properly identified and accuracy is the percentage of subjects (patients with AD and control subjects) correctly recognized. The Area Under the ROC Curve (AUC) is a single number which summarizes all the performance [9].

Table 1. Statistical Analisys of *RP* bands and spectral ratios parameters obtained by WT and STFT

Processing	Relative power (*RP*)						Spectral ratios			
	delta	*theta*	*alpha*	*beta1*	*beta2*	*gamma*	r_1	r_2	r_3	r_4
WT Bior3.5	0,008	0,0004	0,016	0,0005	0,005	N.S.	0,0005	0,0005	0,002	0,003
STFT	N.S.	0,0005	N.S.	0,0001	0,004	N.S.	0,003	0,002	0,006	0,02

N.S. – Not Significant

2.5 The Artificial Neural Network

The ANN was a pattern recognition feed-forward ANN with a Logsig activation function, SCG as the training algorithm, cross-entropy as the error function, the output layer with 1 node, input layer dependent on the features selection combination and finally one hidden layer with a variable number of nodes per methodology and variation. To prevent the overfitting of ANN during the training process we calculated the optimum Weight Decay (Wd) parameter. Wd prevented the weights to participate fully in the modeling process of ANN to the training set. Wd allowed us to avoid the use of the validation set [10].

3 Methodologies

Concerning the EEG processing two methodologies were followed. The objective lied with getting the distinctive information of the EEG in a compact form to serve as input to the ANN, enabling it to learn. In Methodology 1 we used WT. Bior 3.5 and in Methodology 2 we used STFT as EEG signal processing.

3.1 Methodology 1 – WT

We calculated the principal components of four characteristics (r_1, r_2, *RP(theta)*, *RP(beta1)*) obtained by WT Bior 3.5, which showed the four lowest p-values (Table 1) by subject with the PCA technic. In order to determine how each variable behaves and contributes to the components 1 and 2, the eigenvectors of the features were projected in xy by a biplot (Fig.1). It was found that the second component distinguished between the characteristic feature r_1 and r_2, exhibited a positive and negative vectors, respectively. The two vectors representing r_1 and r_2 showed an opposite direction, this means that the two variables exhibited no overlapping values; this indicated that r_1 and r_2 made a good combination for input ANN. The other features revealed a small vector; they may lead ANN into error therefore only r_1 and r_2 were chosen to be the combination parameters for the ANN entry.

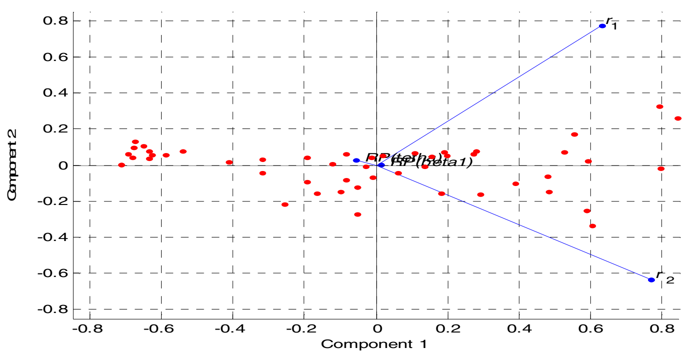

Fig. 1. Principal components Biplot of r_1, r_2, *RP(theta)*, *RP(beta1)*

Variation 1. In this variation the signal of each electrode was averaged along the successive segments of 5 seconds length. The electrodes belonging to the same subject were forced to be in the same set.

Table 2. Dimension of training and test sets

Dimension Training set	Test set	*Input nodes of ANN*
2x494	2x152	2

To prevent the ANN training set overfitting we calculated the optimum Wd parameter. In order to select the best Wd and the number of hidden layer nodes, we used the graphic showed in Fig.2. In the figure it can be seen the distribution of AUC parameter, resulting by the ROC analysis of the ANN leave-one-out-cross-validation-process for the training set. After a short analysis of the graphic (Fig.2), we chose 0.05 of Wd and 5 nodes for the hidden layer to classify the test set by ANN.

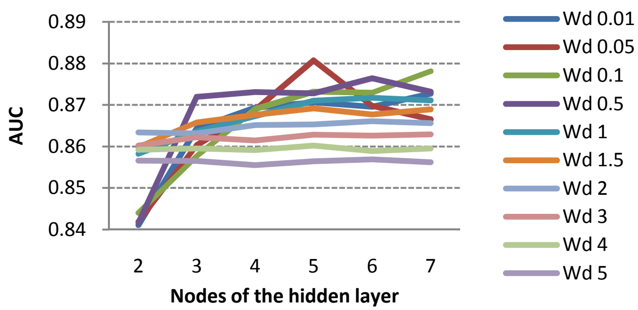

Fig. 2. Values of AUC along the nodes of the hidden layer, for different kinds of Wd values

Variation 2. In this variation each length of 5 seconds, the signals of the 19 electrodes was averaged to produce the so called grand average of 5 seconds length, corresponding to one input output pair for the ANN. The successive 5 seconds grand average signals of one subject were forced to belong to the same set.

Table 3. Dimension of training and test sets

Dimension		*Input nodes of ANN*
Training set	Test set	
2x780	2x287	2

We did the same Wd analysis as in variation 1. After a short analysis of AUC values, we chose 0.1 of Wd and 7 nodes for the hidden layer to classify the test set by ANN because this parameters provide more AUC for the training data set.

3.2 Methodology 2 – STFT

We calculated the principal components of four characteristics (r_1, r_2, *RP(theta)*, *RP(beta1)*) obtained by STFT, which showed the four lowest p-values (Table 1) by subject with the PCA technic. In order to determine how each variable behaves and contributes to the components 1 and 2, were projected the eigenvectors of the features in xy by a biplot (Fig.3).

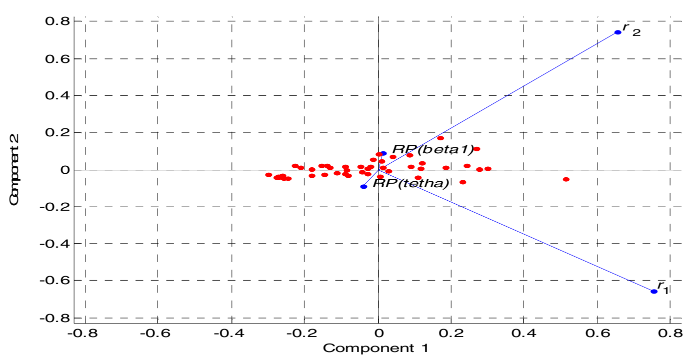

Fig. 3. Principal components Biplot of r_1, r_2, *RP(theta)*, *RP(beta1)*

The two vectors representing *RP(beta1)* and *RP(tetha)* showed an opposite direction, this means that the two variables exhibited no overlapping values ; this and the significant differences between the p-values of them and the p-values of r_1 and r_2 (Table 1), indicated that *RP(beta1)* and *RP(tetha)* providing a good combination for input ANN. And so, only *RP(beta1)* and *RP(tetha)* were chosen to be the combination parameters for the ANN entry.

Variation 1. The same average implemented in variation 1 for the methodology 1 was applied.

Table 4. Dimension of training and test sets

Dimension		***Input nodes of ANN***
Training set	Test set	
2x494	2x152	2

We used the same Wd analysis as we did in the Methodology 1, to prevent the ANN overfitting to the training set as well as to select the nodes of the hidden layer and the Wd parameter to classify the test set. After a short analysis of AUC results, we chose 1 of Wd and 4 nodes of the Hidden Layer, to classify the test set by ANN, because this parameters provide more AUC for the training data set.

Variation 2. The same average implemented in variation 2 for the methodology 1 was applied.

Table 5. Dimension of training and test sets

Dimension		***Input nodes of ANN***
Training set	Test set	
2x780	2x287	2

We did the same Wd analysis as in variation 1. After a short analysis of AUC results, we chose 0.01 of Wd and 7 nodes of the Hidden Layer, to classify the test set by ANN because this parameters provide more AUC for the training data set.

4 Classification Results

The ANN classification results were evaluated by some parameters extracted by the ROC curve. Table 6 presents de results for the two methodologies and respective variations. The results are presented as the AUC, sensitivity, specificity and accuracy as defined previously in section 2.4, measured under the test set (T.C.) and all data set (C.V.)

Table 6. Classification results obtained by the two Methodologies and variations

Parameters	Methodology 1				Methodology 2			
	Variation1		Variation2		Variation1		Variation2	
Type of Classification	T.C.	C.V.	T.C.	C.V.	T.C.	C.V.	T.C.	C.V.
AUC	**0,97**	0,87	0,90	0,85	0.83	0,83	0,81	0,83
Sensitivity	**92,1%**	78,2%	87,0%	74.8%	76,3%	69,9%	73,6%	74,0%
Specificity	90,8%	82,0%	88,0%	77,6%	**92,1%**	75,5%	90,7%	80,4%
Accuracy	**91,5%**	79,7%	87.5%	76.1%	84,1%	73,2%	83.3%	76.8%

T.C. – Test set classification; **C.V.** – ANN Leave-one-out-cross-validation with all EEG data sets.

5 Discussion and Conclusions

After the analysis of Table 6 results, we could conclude that the Methodology 1 generally bring us better results than methodology 2, except for the specificity. The Methodology 1 was performed using the WT and the Methodology 2 using the STFT. The methodology 1 variation 1 was the one that achieved the best results in the test set with 0.97 AUC, 92.1% of Sensitivity and 91.5% of Accuracy. The best results within the all EEG data sets were also achieved by WT variation 1 with 0.87 AUC, 78.2% of Sensitivity, 82.0% of Specificity and 79.7% of Accuracy. Variation 1 generally produced better results than variation 2 under the two methodologies.

Generally the use of only two nodes in the ANN input layer can be scanty towards the capabilities of a normal ANN. But in this study the used ANN is specialized in pattern recognition with an error function (cross-entropy) that is optimized for the discrimination of two distinct groups with a few nodes in the input layer, showing usefulness in the resolution of present problem [10].

Some limitations for this type of study arise, because we loss some spatial information when we retaining only the average measures over the channels, and also because, we assumed that each electrode averaged along the successive segments of 5 seconds length was a subject and each grand average of 5 seconds was a subject too. In the future we must got more EEG signals to ensure generalization. It should also be mentioned that the detected increase of EEG regularity is not specific to AD, it appears in others dementias including Parkinson's disease, epilepsy, vascular dementia and schizophrenia [3].

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Architecture of Health Information Infrastructure: The Case of the United States of America

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Abstract. The Health Infrastructure in the U.S. is called the National Health Information Network (NHIN) which is composed of regional Health Information Exchange (HIE) hubs. This approach has been exercised since 2008. However, there is a lack of one top-down comprehensive architecture of this system, which is being developing by each state individually. This paper provides the top-down model of such architecture, perhaps the first one which is made. The paper defines basic components of that system. Also some issues of security and privacy of stored and exchanged data are disputed. By the end, the paper provides conclusions regarding the issues of its implementation.

Keywords: National Health Information Infrastructure, Health Information Architecture.

1 Introduction

This investigation contains the background of the current policy of the U.S. National Health Program (2011), it particularly identifies the components of that program, which later will be integrated into an architecture of health information infrastructure. Its security and privacy issues will be discussed. The conclusion will assess the feasibility of the presented architecture.

The Health Infrastructure in the U.S. is called the National Health Information Network (NHIN) which is composed of regional Health Information Exchange (HIE) hubs. This approach has been exercised since 2008. HIE is defined as the mobilization of health care information across organizations within a region, community, or hospital system. The goal of HIE is to facilitate access to and retrieval of clinical data to provide safer, more timely, efficient, effective, equitable, patient-centered care. HIE should be also useful to Public Health authorities to assist in analyses of the health of the population [10].

HIE systems should facilitate physicians and clinicians in meeting high standards of patient care through electronic participation in a patient's continuity of care with multiple providers. Secondary health care providers should benefit through reduced expenses associated with duplicate tests, time involved in recovering missing patient information, paper, ink, associated office machinery, manual printing, scanning and faxing of documents, the physical mailing of entire patient charts, manual phone communication to verify delivery of traditional communications, referrals, and tests

M.M. Cruz-Cunha et al. (Eds.): CENTERIS 2011, Part III, CCIS 221, pp. 282–288, 2011.

results. According to an internal study at Sushoo (FL) HIE, a single-clinician practice spends $17,160/year associated with the current method of exchanging patient's health information (retrieved on 2010-5-31 http://www.sushoo.com/sushoo-demo.html).

2 Security Issues of the National Health Information Network

Recent revelations of "secure" data breaches at centralized data repositories, in banking and other financial institutions, in the retail industry, and from government databases, have caused concern about storing electronic medical records in a central location. Records that are exchanged over the Internet are subject to the same security concerns as any other type of data transaction over the Internet.

The Health Insurance Portability and Accountability Act (HIPAA) was passed in the US in 1996 to establish rules for access, authentications, storage and auditing, and transmittal of electronic medical records. This standard made restrictions for electronic records more stringent than those for paper records. However, there are concerns as to the adequacy of implementation of these standards in practice.

3 Privacy Issues of the National Health Information Network

One major issue that has risen on the privacy of the U.S. network for electronic health records is the strategy to secure the privacy of patients. Former US president Bush called for the creation of networks, but federal investigators report that there is no clear strategy to protect the privacy of patients as the promotions of the electronic medical records expands throughout the United States. In 2007, the Government Accountability Office reports that there is a "jumble of studies and vague policy statements but no overall strategy to ensure that privacy protections would be built into computer networks linking insurers, doctors, hospitals and other health care providers" [7].

The privacy threat posed by the interoperability of a national network is a key concern. One of the most vocal critics of EMRs, New York University Professor Jacob M. Appel, has claimed that the number of people who will need to have access to such a truly interoperable national system, which he estimates to be 12 million, will inevitably lead to breaches of privacy on a massive scale. Appel has written that while "hospitals keep careful tabs on who accesses the charts of VIP patients," they are powerless to act against "a meddlesome pharmacist in Alaska" who "looks up the urine toxicology on his daughter's fiancé in Florida, to check if the fellow has a cocaine habit" [3]. This is a significant barrier for the adoption of an EHR. Accountability among all the parties that are involved in the processing of electronic transactions including the patient, physician office staff, and insurance companies, is the key to successful advancement of the EHR in the U.S. Supporters of EHRs have argued that there needs to be a fundamental shift in "attitudes, awareness, habits, and capabilities in the areas of privacy and security" of individual's health records if adoption of an EHR is to occur [6].

So far, The U.S. Department of Health and Human Services takes no action on complaints under HIPAA, and medical records are disclosed under court orders in legal actions such as claims arising from automobile accidents. HIPAA has special restrictions on psychotherapy records, but psychotherapy records can also be disclosed without the client's knowledge or permission. For example, Patricia Galvin, a lawyer in San Francisco, saw a psychologist at Stanford Hospital & Clinics after her fiancé committed suicide. Her therapist had assured her that her records would be confidential. But after she applied for disability benefits, Stanford gave the insurer her therapy notes, and the insurer denied her benefits based on what Galvin claims was a misinterpretation of the notes. Stanford had merged her notes with her general medical record, and the general medical record wasn't covered by HIPAA restrictions [6].

4 Basic Data Entry of the National Health Information Network

The whole HIE architecture is based on a set of related electronic data entry (records), for

- Electronic Medical Records about patients (EMR)
- Electronic Laboratory Records (ELR)
- Electronic Image Records (EIR)
- Computer Physician Order Entry (CPOE) at hospitals
- Electronic Pharmacy Records (EPR)
- Personal Health Records (PHR) collected by individuals and eventually shared with appropriate health care providers
- Disease Management System (DMS), maintained by Insurers
- Other

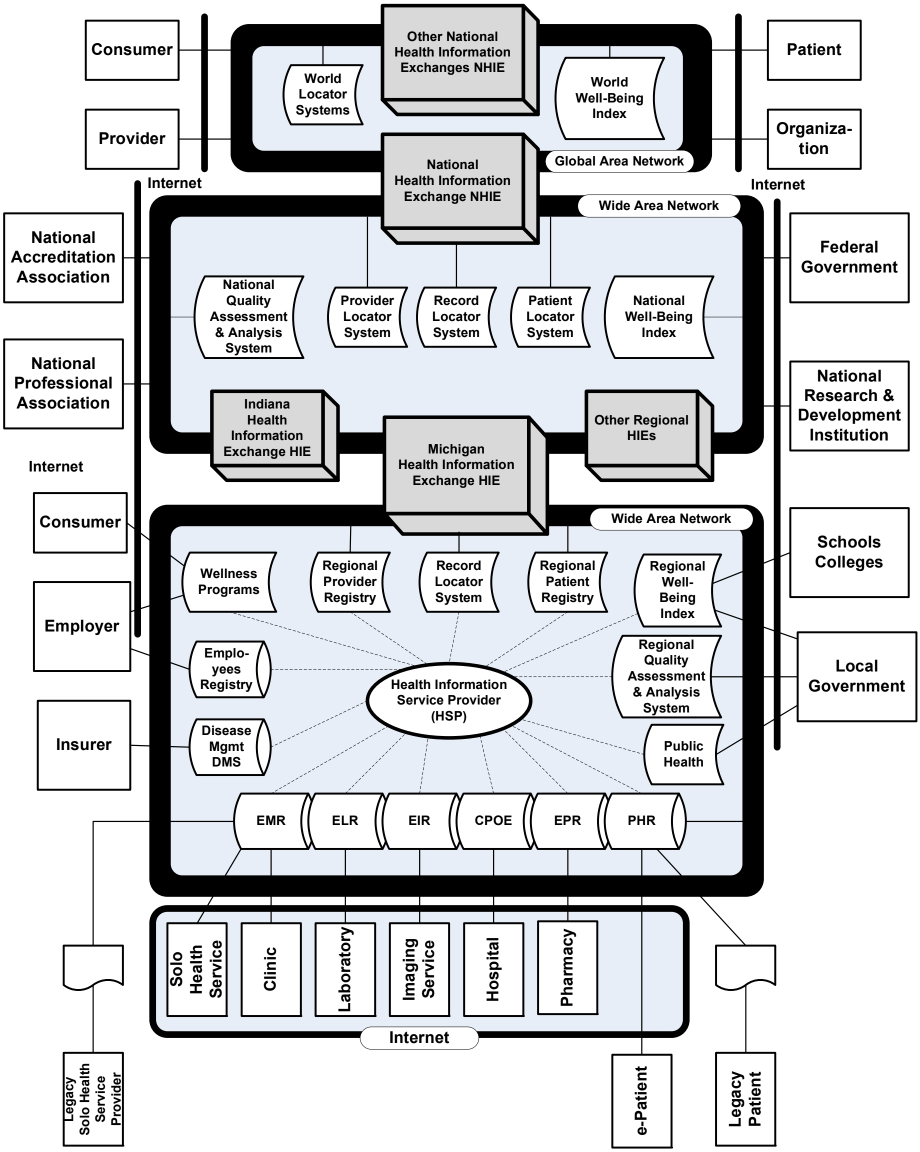
The advantage of these electronic records is that they can "talk to each other" and reduce chaos and errors. In the United States, Great Britain, and Germany, the concept of a national centralized server model of healthcare data has been poorly received. Issues of privacy and security in such a model have been of concern.

(Retrieved on 2010-5-31; e-Health Insider (UK). January 2008. http://www.e-health-insider.com/news/3384/german_doctors_say_no_to_centrally_stored_patient_records)

Privacy concerns in healthcare apply to both paper and electronic records. According to the average medical practice, roughly 150 people (from doctors and nurses to technicians and billing clerks) have access to at least part of a patient's records during a hospitalization, and several, providers and other entities that handle providers' billing data have some access also (e-Los Angeles Times).

5 An Architecture Model of the National Health Information Network

Within the private sector, many companies are moving forward in the development, establishment, and implementation of medical record banks and health information exchange.



(EMR-Electronic Medical Record, ELR-Electronic Laboratory Record, Electronic Image Record, CPOE-Computerized Physician Order Entry, Electronic Pharmacy Record, Personal Health Record (The Targowski Model)

Fig. 1. The Architecture of National Health Information Exchange Network for the U.S (2010)

By law, companies are required to follow all HIPAA standards and adopt the same information-handling practices that have been in effect for the federal government for years. This includes two ideas: standardized formatting of data electronically exchanged and federalization of security and privacy practices among the private sector. Private companies have promised to have "stringent privacy policies and procedures." If protection and security are not part of the systems developed, people will not trust the technology nor will they participate in it. So, the private sector knows the importance of privacy and the security of the systems and continues to advance well ahead of the federal government with electronic health records.

In health care files and databases, paper-based systems are difficult to keep updated and to share with other health care providers and users. If a given health care provider does not have good enough information technology at hand, it can acquire services of independent Health Information Services Providers (HISP).

The architecture of Health Information Exchange Network is depicted in Figure 1. This architecture (according to this author) is based on private Wide Area Networks (WAN) and Global Area Network (GAN) and the Internet. The U.S. Office of National Coordinator for Health Information Technology (ONC) plans the use of the Internet only. It is recommended contrary to American businesses' practice which organized data transmission on private networks (MAN, WAN, GAN, VAN) due to higher security than which can be achieved on the Internet. According to the ONC, the NHIE will apply software which will comply with the access and security standards defined in the CONNECT Project.

The presented architecture of the HIE Network includes two very important systems at the regional and national levels: the Quality Assessment and Analysis System (QAAS) and Well-Being System (WBS). Furthermore, there planned at the regional and national levels; locators of records, patients, and providers (awkward, needs clarification).

6 Systems of the National Health Information Network

The planned National Health Information Network has the following four levels of information processing systems:

- Level 1 "Local" – Includes health service providers, such as: health clinics, health laboratories, imaging services, hospitals and so forth. At this level health service data about patients (consumers, employers, insurers) are entered under systems' form of
    - Electronic Medical Records (EMR),
    - Electronic Laboratory Records (ELR),
    - Electronic Pharmacy Records (EPR),
    - Personal Health Records (PHR), and other.
- Level 2 – "Regional" – Includes health insuring employers, insurers, local governments, and so forth, which create the State Health Information Exchange (HIE) services, which will use the following systems;
    - Operational systems: Employees Registry, Regional Patient Registry, Regional Provider Registry, and Record Locator System,

  - Quality control systems: Regional Well-Being Index, Regional Quality Assessment & Analysis System, Public Health System,
  - Program Informing Systems: Disease Management System, Wellness Program, and so forth.

- Level 3 “National” – Includes federal government, national research & development institutions, national accreditation associations, national health professional associations which create the National Healthy Information Exchange (NHIE) and will use the following systems:

  - Operational systems: Provider Locator System, Patient Locator System, Records Locator System,
  - Quality control systems: National Well-Being Index, National Quality Assessment & Analysis System
  - Gateways to other regional HIE(s)

- Level 4 “International” – includes foreign health services providers, insurers, which provide services for the American patients or the American health services providers which provide services for foreign patients being treated in the U.S. They will apply the following systems:

  - Operational systems: World Locator System
  - Quality control system: World Well-Being Index.
  - Gateways to National HIE (s).

These systems create a complex system environment, which should be planned, design, and implemented with the mix strategy, including top-down provided standards and bottom-up data entry processes, controlled by the local, national, and international users. This kind of the system complex is difficult to implement, since the health care industry, the largest business in the world, is full of contradictory goals and strategies. Very often the planned “chaos” serves better than the organized systems?

7 Conclusion and the Future Work

At the time of publishing this paper (Fall 2011), the author is rather pessimistic about possibility of successful implementation of this architecture. The American national political and societal climate is negative for large-scale and innovative initiatives (4). The status quo is the most popular policy among established political and professional leaders (10). This is because the 19th century attitude was supposedly very successful in developing of Americanism (efficient way to wealth and “happiness”).

Unfortunately, after the passing of almost two centuries, today we enter a new epoch of new societal issues and required solutions, which require bold conceptualization and tough choices, through the 21st century [8]. However, despites of these new challenges the most powerful country in the world must search for new ways to wealth and happiness of its citizens [9]?

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Cloud Computing Enhanced Service Development Architecture for the Living Usability Lab

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Abstract. As life expectancy increases, so does the number of ambient assisted living (AAL) initiatives. These IT initiatives often traverse several research fields; from embed devices to multiple data streams analysis. Advanced processing and reasoning of such data streams poses a complex problem usually solved using local processing resources. This paper addresses this problem from a cloud computing perspective.

Keywords: Ambient Assisted Living, Cloud Computing, Living Lab, Telerehabilitation.

1 Introduction

Living Usability Lab (LUL) [1,2] is a joint academia-industry R&D initiative, started in January 2010, aiming at creating the conditions to develop and evaluate innovative services for the Elderly initiative of industry and research. Essentially, it is a living laboratory to test new approaches to the ambient assisted living initiative.

Nuclear to the project is its attention to usability, multimodal interaction, design for all and the exploration of new opportunities opened by next generation networks. Multimodality is essential to support intuitive and natural interfaces effectively humanized.

Considering the high demands on the overall AAL system quality and consequently on software and system engineering, user acceptance is an absolute necessity. Therefore, the early involvement of end users in the design process assumes a high importance to meet the actual needs of the future users in their daily life.

Although the importance of the user involvement and user participation in the design process has been recognized as essential, there is a need to further developments in the daily practice, through the use of innovative strategies. Living Lab is an emerging research methodology which includes the user involvement by taking into account the micro-context of their daily activities.

By addressing the scenario of elderly at home with these specificities, the project is in line with the most recent developments in the broad area of Ambient Assisted Living (AAL).

LUL is a living laboratory. One of the current projects in the laboratory is TeleRehabilitation [3].

M.M. Cruz-Cunha et al. (Eds.): CENTERIS 2011, Part III, CCIS 221, pp. 289–296, 2011.

The main purpose of this paper is to present and discuss a possible research direction on LUL project where services and applications may embrace a distributed computing scenario. Given the current hype on cloud computing, and considering the benefits (scalability, processing, storage, etc.) arising from its usage, there is the need to understand how the LUL project can be adapted to integrate Cloud Computing on the production system. Furthermore, there is the need to understand the pros and cons of venturing through the cloud.

This is an essay paper about the usage of cloud computing services to enhance LUL. The main goal is to assess the pros and cons of adopting cloud computing. The extent of the externalization of LUL's system must also be considered.

2 State of the Art

Even though there are several AAL initiatives ([4-6] refer to recent work), few projects rely or are based on cloud computing solutions. However, there are a few exceptions worth mentioning. This section covers some of the approaches in production sites.

In [7] authors present an architecture for a Secured WSN-integrated Cloud Computing for u-Health Care. The cloud computing integration was necessary for faster, cheaper and more reliable processing of information.

Authors argue that large, heterogeneous and complex data processing and visualization can be computing intensive, especially for real time scenarios. Processing of raw sensors data, handling incorrect data, filtering information, combining different sensor data and display such information in a user friendly manner are but a few of the operations in place in the information workflow. The amount of sensors and information (environmental, imagery, video, audio) that can be monitored and cross compared at a given time, and considering the huge amount of information (hundreds of samples per second per device, burst frames, etc.) that such sensors represent, a huge processing power is required. This approach is also valid when considering that on top of such real time information, users require historical analysis, information data-mining, context awareness, ontologies processing and other high levels. In this case, the huge processing capabilities of cloud computing can be a key factor to achieve the desired performance and results.

The processed information is available to medical staff upon successful authentication.

In [8] authors present AMiCA, a multi-level layered architecture with intelligent reasoning and decision-making support. AMiCA pushes into the cloud the sensors' and context gathers' base communication line.

Both projects use cloud computing essentially for computing purposes.

3 LUL

The project's main concepts are the Home Site, the Specialist Site and the Main Server.

Home Site – it represents the location of the patient. It may be his home or his hospital room. Each home site may hold a set of resources available as services (temperature sensors, video camera, motion sensors, television, speaker, microphone, etc.).

Health professional (Specialist) Site – it represents the location of the specialist. A specialist is typically a doctor. The specialist site is usually his office. Each specialist site may hold a set of resources available as services acting as clients of the information sent by the home site's services.

LUL main server – it is responsible for maintaining a complete list of both specialists and homes registered in the system. For each registry, the server also holds a list of its available services. Along with basic registration functionality, LUL server is also responsible for maintaining a scheduler. Each scheduler event refers:

- Home identification,
- Specialist identification,
- List of allocated resources,
- Event start and end time.

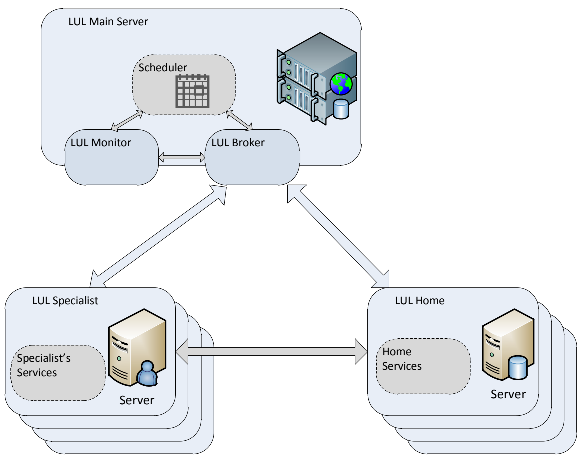

Fig. 1. LUL Remote assistance main blocks

Fig. 1 represents an overview of LUL's remote assistance building blocks. Based on the scheduling information, the LUL server is responsible for ensuring the communication between the LUL specialist and the LUL home. At the event's starting time, the LUL server informs both parties of which services should be started and sends them connection and configuration details for the session:

- Direct device to device communication addresses,
- Specific session and device configuration settings.

After this step is completed, the monitoring features of the LUL server will continuously assess the established connections and may signal the broker to restart all or any service that fails during the event.

Fig. 2 represents the complete set of communications amongst services, broker and monitor. Before any session may take place, both home and specialist services must be registered in the broker. This registration process results from a direct communication between the services and the broker. Each device registers its connection endpoints, capabilities and security requirements.

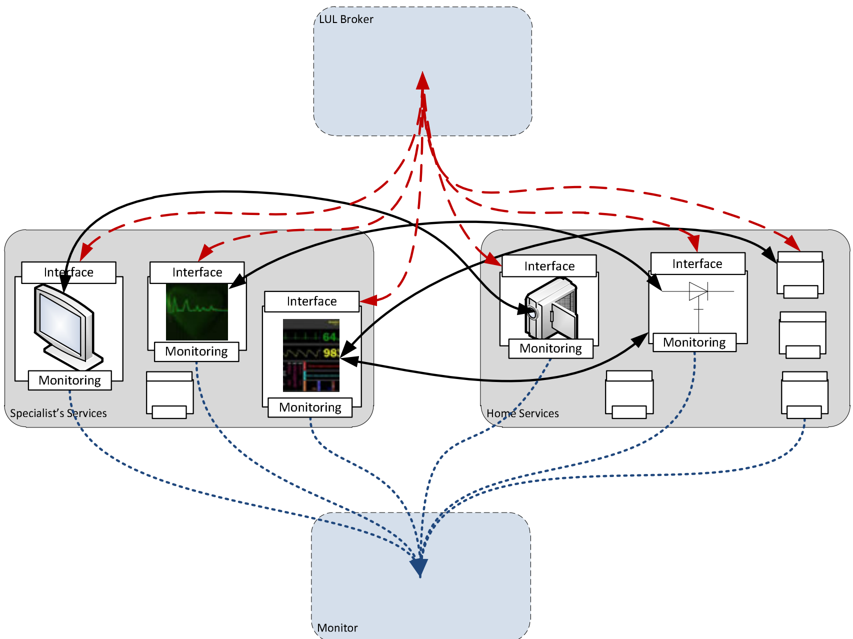

Fig. 2. Communication amongst services

To start a session, both parties (specialist and home) must already be connected to the LUL main server. This initial connection ensures their readiness for the session. Pending request from the specialist regarding an upcoming event, the broker initiates a work session between the services. During this process the broker sends configuration and crossed endpoints details downwards the services. This may be compared to a traditional doctor's appointment: at the designated time, the patient arrives at the doctor's office and waits for its turn (connection phase); on its turn, all the required specialist services can be used to diagnose the patient (session start phase).

Depending on the service's features, one service may establish one or more connections simultaneously with other services. For instance, a sensing service may be connected to two different display services on the specialist side; or a monitoring display service may be connected to more than one sensing service.

As stated, after this initiation phase, each device pushes activity status information to the monitor.

3.1 Deployed Services

Each service may aggregate a set of devices. These are abstracted by a common interface layer that is also responsible for the communication with the LUL server. An independent monitoring layer is also responsible for sending status information to the LUL server. Fig. 3 illustrates the generic service architecture.

This architecture ensures that for a given service, regardless of the number, type or complexity of the devices, the way that the service communicates with others follows a specific and single protocol. This enables the services to evolve and replace devices by others with better features without disrupting the outside communication layer.

Service interface and monitor communicate with the LUL Main Server using web services. The service-to-service communication may or may not use web services. As an example, the home video service and specialist video display, upon registration and successful connection, send and receive the video stream using Real Time Protocol.

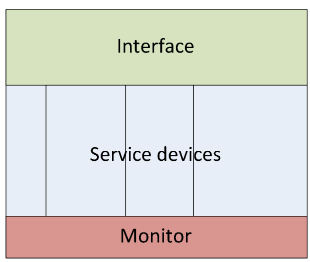

Fig. 3. Generic service architecture

The first service developed aims at making available inside the home and remotely the data gathered by a set of sensors developed by one of the project partners, named BioPlux [9]. For its inclusion, a generic sensor service was developed. The service was developed to be independent of the sensors to be used. The Plux Bio Sensor can be used as any other type of sensor that can appear in the future. The list of currently deployed services include a sensors' service implementation, a specialist sensors display service, a home video service and a specialist video display service.

3.2 LUL @ Cloud – Future Architecture

As with the projects presented in the state of the art section, more advanced usage scenarios require more processing and storage capabilities. To overcome this situation, we propose the off-site processing of all services involved in LUL: Main Server, Specialist Server and Home Server. This way all services may communicate primarily with the off-premises infrastructure.

Considering each deployed service (sensor, camera, speaker, etc.) as an agent, it is possible to automatically propagate its information throughout the off-premises infrastructure. LUL's sites are equipped with fast next generation networks, making the migration from local servers to cloud based servers almost seamless from the communications and latency point of view. Even when considering the nationwide adoption of such project, Portugal has one of the fastest and most widespread fibre optical commercial offerings in Europe [10], meaning that the cloud computing approach will still be valid.

In this scenario there is no need to install extra computational power at the Home site or at the Specialist site, meaning that the deployment of the project itself into new Home Sites becomes cheaper and therefore easier to adopt.

Fig. 4 presents the new block and its interaction with the existing infrastructure. Local server instances are eliminated in this approach. The only precondition is that all services are able to communicate remotely.

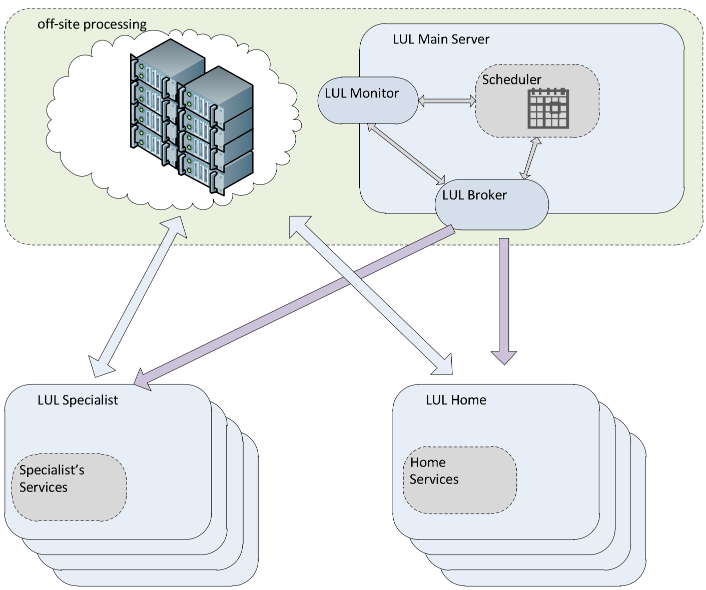

Fig. 4. LUL @ Cloud proposal

The main interactions are still present: at the starting time of an event, the LUL Main Server initiates both the Specialist devices and the Home services. Information flow however, differs from the initial architecture. Information datasets start being pushed from the Home site and consumed at the Specialist site, always traversing through the cloud. The fact that the information datasets all pass through a common location, allows that, for example, a single Home site information stream be directly consumed by several Specialist services, without having to send a duplicate stream from the Home site (information upload) and without the needing of multicast routing. If several Specialist services require a particular stream, then it should be directly downloaded by the requiring services.

The monitoring module, currently running in the LUL Main Server, may be modified to also listen to the streams passing through the cloud. In this case, the traffic added due to monitoring on either Specialist or Home Site would be null.

A simple but effective solution for the data stream is the use of ROS [11], a cloud enabled Robot operating system. ROS is composed by a set of basic information flows consistent with message parsing, organized in a series of topics. Each topic has one or more publishers and zero or more subscribers. Agents (in our case services) push information to the topic and the subscribers get the pushed information.

On top of this first service layer (ROS), the management layer (Main Server) commands the agent's (Site's Services) activity. Their monitoring can be made using the topic/publisher/subscriber use case.

3.3 Discussion

Services and applications in use can be compute intensive, especially at the specialist site, when trying to analyse lengthy patient data records, or when making real time processing of complex information. This off-site processor cloud computing executing based environment means that both peak and off-peak usage can be automatically handled by the cloud, further alleviating the overall cost of running this project.

From the Health professional point of view, the off-site processing element can be interpreted as a Home site with very powerful hardware available. From the Home point of view, the off-site processing element can be interpreted as a regular Specialist that needs access to the information.

Adding to LUL telerehab scenario a ROS based messaging scheme enables the reduction of server equipment on the home site and on the specialist site. Nevertheless, due to the anonymous messaging architecture, special care must be taken to ensure data safety, integrity and confidentiality. . One negative aspect of ROS is that publish and subscribe are anonymous, meaning that it has to be the overall system to guarantee data safety and confidentiality.

An advantage of this scenario is the possibility to rapidly have multiple reasoners analysing the streams passing through the cloud, with no additional cost (in terms of power, resources or bandwidth) from either the Home site or the Specialist site. These high level modules could then be used to trigger warning alerts when certain conditions are be met, or to actively enforce services (on both sites) to perform a given task.

4 Conclusions

This paper presented an overview of LUL's telerehab project, with special focus on the further development of it architecture. This development must consider the need for more processing resources as well as for more resources and services available. Cloud computing was chosen as a common platform to use when replacing the connections for the main server, the health professional site and the home site.

This paper briefly outlines the cloud computing scenario on AAL systems and proposes a new AAL cloud computing approach based on ROS's messaging system.

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A Semantic Web Pragmatic Approach to Develop Clinical Ontologies, and Thus Semantic Interoperability, Based in HL7 v2.XML Messaging

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Abstract. The ISO/HL7 27931:2009 standard intends to establish a global interoperability framework for Healthcare applications. However, being a messaging related protocol, it lacks a semantic foundation for interoperability at a machine treatable level has intended through the Semantic Web. There is no alignment between the HL7 V2.xml message payloads and a meaning service like a suitable ontology. Careful application of Semantic Web tools and concepts can ease extremely the path to the fundamental concept of Shared Semantics. In this paper the Semantic Web and Artificial Intelligence tools and techniques that allow aligned ontology population are presented and their applicability discussed. We present the coverage of HL7 RIM inadequacy for ontology mapping and how to circumvent it, NLP techniques for semi automated ontology population and discuss the current trends about knowledge representation and reasoning that concur to the proposed achievement.

1 Introduction

A pragmatic approach is presented in order to identify the different issues faced and for each one of them we discuss the possible and feasible solutions according to the State-of-the-Art in the Semantic Web and Artificial Intelligence science fields. Paramount interest arrived due to the very recent acknowledgment of the clinical practice encoding communities about the possibilities of redirecting efforts to capture the "meaning of data" instead of coding directed to a particular purpose like reimbursement or government funding and reporting as introduced by Cimino in [20].

Although the most significant amount of work in ontology enrichment and population has been done in the Biomedicine research area as illustrated by [2], taking into account the considerations introduced in [1,5] and more recently illuminated by the developments in technology and tooling as referred in [2] we introduce here the proposal of taking advantage of standardization of messaging in EHR[1] to develop the tooling to finally evolve into "evidence based harmonization" in ontology development meant mainly for clinical practice. The completeness and full coverage of ISO/HL7[2] 27931:2009 Standard will allow solutions that do not fall short in particular fields of the different medical specialties. To accomplish a successful work the resulting ontologies have to achieve the sort of user-friendliness, reliability, cost-effectiveness, and breadth of coverage that is necessary to ensure extensive usage as introduced by Smith in [11].

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[1] Electronic Health Record.

[2] Health Level 7.

M.M. Cruz-Cunha et al. (Eds.): CENTERIS 2011, Part III, CCIS 221, pp. 297–306, 2011.

Several factors have to be judiciously handled using all the latest trends in technological and scientific development, among these are the proper selection of what ontologies shall be used for learning/enrichment and all the pragmatic aspects that may render broad usage of the resulting automatically produced knowledge. For all of these we suggest what we feel are the most promising, or already proved on the field, techniques that will lead us to the above explained desiderata.

2 Ontology Population in Health

The amount of Clinical data digitally preserved in EHRs is colossal, ever increasing and numerous problems have to be devised and solved as reviewed by Meystre et al. [1] and Liu et al. [13]. Most of the clinical data is in text form coming either from typing entry, transcription from dictation or from speech recognition applications. Accurate coding is necessary for comparability, auditability and last but not least important, accountability. We will figure out a "picture of Healthcare provisioning" through clear identification of the meaning of the available data and not only by the capability of cataloging and codifying that huge amount of data.

2.1 From Clinical Text Information Extraction to Ontology Population

Ontology population/enrichment is performed through Information Extraction from the clinical texts embedded in the messages. IE[3] is a specialized sub-domain of NLP[4] that returns pieces of information from text analysis, unlike IR[5] that returns documents. Facts extracted from documents must refer to a common agreed upon meaning as expressed in some ontology to function as a knowledge enhancement tool. As illustrated in the review by Meystre et al. [1] complemented by the review in [13] many IE methodologies are already thoroughly presented and discussed, and all those considerations shall be taken into proper account in the present work. Aligning the extracted information in form of Clinical Concepts and its relationships in Clinical Practice directed ontologies involves classification to some specific ontology (or a network of them) using several NLP techniques. These tasks form a pipeline of NER[6] , WSD[7] [21] , CRR[8] [22,23,24] , DR[9] , EAV[10] [25], and finally clinical concept matching being these concepts the 'cognitive constructs' introduced by Cornet et al. in [26]. The ontology to be improved will then be refined and developed from some first ontologies in the Biomedical domain. For this purpose different valuable approaches from the symbolic, statistic and hybrid approaches reviewed by Liu et al. in [13] will be discussed ahead in Section 4 and we present here the problems involved in tagging the information so that it will be usable for the ontology enrichment.

3 Information Extraction.
4 Natural Language Processing.
5 Information Retrieval.
6 Named Entity Recognition.
7 Word Sense Disambiguation.
8 Co-Reference Resolution.
9 Discourse Reasoning.
10 Extraction of Attributes and Values.

2.2 Named Entities Disambiguation (NED)

GSO[11] will provide us with the controlled vocabularies that can unambiguously co-relate the found term with its due meaning and simultaneously aligning in the direction of a suitable CRR contributing to the desired Concept Acquisition. The fine selection of the GSO will entail the quality of the approval/rejection option for every singular case.

2.3 The Corpora and Its Size Relevancy

The size of the corpora itself is an open issue. Several recent papers[13] question the value of using an over-sized amount of text. In our particular case that of clinical notes resident in HL7 messages. We believe that the proper dimensionality of the corpora will be self adjusted by the factor of rejection attained in the pre-processing operations of our proposal. That is, if during the spell checking, document structure harmonization, tokenization, de-identification, term pruning, word sense disambiguation, named entities disambiguation and semantic concept choice, for instance, tasks no "high valued disambiguation" is achieved then that particular case will get into the rejected corpora and so the refined corpora will only have those items that provide real learning potential.

2.4 Semantic Similarity and/or Patient and Clinical Distance between Cases

Semantic distance is based on weighted path length between concepts. A particular application here is to classify the proximity between our refined corpora messages for the purposes of clustering, indexing and context insertion for classification. In the general case of using semantic methods for text analysis there are some generally available, proved and used on the field. They vary mainly around two different approaches based in linear algebra or probabilistic modeling like the Principal Component Analysis -PCA [9], Vector Space Model -VSM [10], Latent Semantic Analysis -LSA [7], Probabilistic LSA -PLSA [6] and Latent Dirichlet Allocation -LDA [8]. A distinguishable characteristic of our sub-domain of interest resides in the complexity of finding semantic similarity between two terms hence we propose the use of the method built upon SNOMED CT presented by Batet et al. in 2010 [15] which essentially provides independence from the semantic similarity search and the underlying working methods also carefully reviewed in the referred work. For use in a coherent strategy of developing our evidence based population the major concern is not about which method is more appropriate but to develop an interface for our "ontology aligned population" that every chosen method shall adhere to.

2.5 De-identification Issues

This is an extremely important duty because all clinical data has to be cleansed of the possibility of re-identifying in many of the purposes that may be of interest in our work. In the U.S. de-identification itself is due to be in accordance to a specific standard, namely the so-called "Safe Harbor" by the HIPAA[12] that implies the proper

[11] Gold Standard Ontologies.

[12] Health Insurance Portability and Accountability Act.

anonimization of 18 patient identifiers including names, all geographical subdivisions smaller than a state, all elements of dates related to the individual, identifying numbers like phone, fax, social security, medical record, health plan , accounts, certificate or license, vehicle identification, device identification or serial numbers, e-mail addresses, URLs, IP Addresses, Biometric Identifiers, full face photographs and any other uniquely identifying numbers or codes.

Two possibilities can be of concern, whether we are directing our pre-processing labors to populate aggregate ontology information and then it seems adequate to have the kind of care suggested by the US Government and similar identifying removal practices must be enforced or our work is directed to other useful endeavors like EHR enrichment through automated reasoning and decision support aids in the clinical ground and then the identity must be removed but the record tagged for follow up purposes. For instance to correlate diagnostic findings to exams and to therapy applied later.

3 Automated Ontology Population

IE typically requires some "pre-processing" such as spell checking, document structure analysis, sentence splitting, tokenization, WSD, part-of-speech tagging, and some form of parsing namely for identification of strings representing quantities or abbreviations, as in laboratory results for instance. The telegraphical form that is common among clinicians also poses some constraints to the usual NLP techniques used in other fields. Contextual features like negation, temporality, and event subject identification are crucial for accurate interpretation of the extracted information, most work however has been developed so far, as presented by Demner-Fushman et al. in [12].

Our full automation proposal includes two harmonizing steps with the currently available techniques and services that qualify for the considered mission. The first is using the above picked harmonization GSO to provide alignment. The second step is to use the available CORE[13] subset of the UMLS[14] Methathesaurus to further simplify and certify our terminology. It is possible in a loosely way to query data remotely via Web Services using the API available in the UTS[15] , a service of the U.S. NLM[16] , to validate against the referred CORE Problem List and Route of Administration Subsets of SNOMED CT[17] . The software needed to accomplish this, as all of the work presented here, has a Loosely Coupled Architecture based in Web Services and certified, auditable messaging as enforced in the ISO/HL7 standard.

4 Clinical Practice Ontology Population vs. General Ontologies

Relations specifically associated to Biomedicine or Clinical Practice retain knowledge associated with the clinical domain. Apart from relations such as is-a and part-of, biomedical ontologies also contain domain specific relations such as has-location,

[13] Clinical Observations Recording and Encoding.
[14] Unified Medical Language System.
[15] UMLS Terminology Services.
[16] National Library of Medicine.
[17] Systematized Nomenclature of Medicine - Clinical Terms.

has-manifestation or clinically-associated-with. These relations are, however, nothing but that. That is, relations. And this turns them semantically transparent, no specific domain knowledge differentiates these relations from any other given the appropriate definition (cardinality, direction, object, datatype and annotation properties) which for proper computability purposes can be achieved with the adequate OWL DL [18] representation. Currently several tools exist for bi-directional converting which can automatically transform OBO[19] ontologies into the OWL-based format used by the Semantic Web namely OWL DL [3]. The problem of defining what are the ontologies that should be considered as adequate for proper enrichment will be discussed ahead in Section 4.1.

Being standardized in 2009 the language of choice, and consequently the associated tooling, is OWL2. OWL2 addresses key expressive and computational limitations of OWL. By adding new constructs to the language, OWL2 more directly supports medical applications. For example, so called "role chains" allow ontologists to express the connection between spatial relations and part-whole relations, e.g., if a fracture is located on a bone which is part of a leg, that fracture is a fracture of that leg.

4.1 Adequate Ontologies for Harmonization

The formation of the possible list of Ontologies shall take in consideration the steps suggested in the Ontology Engineering area with the developments and tools introduced in recent years. What is a 'good' ontology to use as a GSO for "evidence based harmonization"?

Items to be evaluated are usage, application performance, data coverage, corpus fit and reasoning adequacy for instance, with quality criteria as accuracy, adaptability, clarity, completeness, computational efficiency, conciseness, consistency and organizational fitness. Tools and methodologies that perform this categorization like OntoClean [27] are available. Ontologies are to be gathered in a Clustered Network and it seems advisable to use foundational Ontologies covering: Anatomy like the FMA[20] , the foundries from OBO like Biological Process[21] , Adverse Event Reporting[22] , Human disease[23], Infectious Disease[24] , Symptom[25] and time ontologies like DAML or SUMO for instance. The NeOn[26] toolkit is the reference implementation of the NeOn architecture that entails support for ontology engineering and management, complete ontology lifecycle, different ontology languages (OWL2 or F-Logic[19]) and support for networked ontologies (modules, mappings). It fits naturally in a Java enterprise environment with extensions through plugins and Web Services. Manipulating all the proposed eco-system through Web Service interfacing is the suggested architecture.

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[18] Web Ontology Language Description Logic.

[19] Open Biological and Biomedical Ontologies - http://www.obofoundry.org/

[20] Foundational Model of Anatomy - http://sig.biostr.washington.edu/projects/fm/

[21] http://www.obofoundry.org/cgi-bin/detail.cgi?id=biological process

[22] http://www.obofoundry.org/cgi-bin/detail.cgi?id=AERO

[23] http://www.obofoundry.org/cgi-bin/detail.cgi?id=disease ontology

[24] http://www.obofoundry.org/cgi-bin/detail.cgi?id=infectious disease ontology

[25] http://www.obofoundry.org/cgi-bin/detail.cgi?id=gemina symptom

[26] http://www.neonproject.org/nw/Welcome to the NeOn Project.

For enrichment. The same considerations introduced above for the selection of the collection of ontologies to use as GSO for the pre-processing and harmonizing proceedings may be used to pick the Ontologies that are to be learned/enriched. Naturally the first possible subjects for automated enrichment are some of the OBO foundries themselves like the Ontology for General Medical Science[27] or Ontology of Medically Related Social Entities[28] just to mention two evident candidates. We should be bold enough, however, to ascertain that the pinnacle of the possibilities of the current proposal shall be the capability of gathering a "virtual picture" of the clinicians activity. That is, a photograph of a MD activity, the evaluable and comparable performance of a Service, a Hospital or a Health System at large for instance.

4.2 Shared Semantics and Ontology Harmonization through Modeling around HL7, Its Intentions and Its Flaws

In the 2009 edition of the HL7[29] Version 3 complete suite of specifications some salient features have been focused and the most important as what relates to this work are: (1) A focus on semantic interoperability by specifying that information be presented in a complete clinical context that assures that the sending and receiving systems share the meaning (semantics) of the information being exchanged; (2) Model-based specifications that provide consistent representation of data laterally across the various HL7 domains of interest and longitudinally over time as new requirements arise and new fields of clinical endeavor are addressed. This has proved to be the most far sighted motivation particularity as it enabled the interaction and harmonization within BRIDG[30] [17]; (3) Technology-neutral standards that allow HL7 and the implementers of HL7 standards to take advantage, at any point in time, of the latest and most effective implementation technologies available like the latest trend in developing loosely coupled architectures for integration based in SOA[31] ; (4) A development methodology and metamodel that assures consistent development and the ability to store and manipulate the specifications in robust data repositories rather than as word-processing documents.

A significant amount of problems still are fattening the above bill of fair intentions, mainly in its application to reality:

4.3 HL7 a ill defined Standard?

HL7 is adopted by Oracle as basis for its Electronic Health Record technology; supported by IBM, GE and most major vendors and users like the US DoD VA. In HL7 V2 the realization of the messaging task allows ad hoc interpretations of the standard by each sending or receiving institution. Then vendor products never properly interoperate, and always require mapping software. The solution to this problem is the HL7 RIM or Reference Information Model that was touted as a world standard for exchange of information between clinical information systems. The V3 solution was to

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27 http://www.obofoundry.org/cgi-bin/detail.cgi?id=OGMS
28 http://www.obofoundry.org/cgi-bin/detail.cgi?id=omrse
29 www.hl7.org
30 http://www.bridgmodel.org/
31 Service Oriented Architecture.

remove optionality by having the RIM serve as a master model of all health information, from blood banks to Electronic Health Records to clinical genomics [18] and to be the standard of choice for countries and their initiatives to create national EHR and EHR data exchange standards.

Yet, despite the claim of being "credible, clear, comprehensive, concise, and consistent", as well as "universally applicable" and "extremely stable", the huge efforts themselves undermined several problems that surfaced through the development of the practicalities of implementations.

Questions arose mainly regarding documentation (1) that is divided into 7,573 files, subject to frequent revisions and very difficult to understand marked by sloppy and unexplained use of terms such as 'act', 'Act', 'Acts', 'action', 'ActClass' 'Act-instance', 'Act-object'; scope (2) since the class structure is built upon only two main classes Act and Entity basic categories cannot be agreed upon for common phenomena because the inheritance from the upper classes can be discussed upon. In RIM there is no distinction between an activity and its documentation, an Act is the document about an Act that is, by definition, an intentional action (!) and finally; implementation problems (3) since it had difficulties growing to embrace the technological developments occurred since it was adopted as early as 1997.

4.4 Clinical Notes Acquisition from V2.XML Protocol

As early as 2003, the American National Standards Institute approved the HL7 Version 2 XML Encoding Syntax informally known as HL7 V2.xml. HL7's Version 2.xml messaging standard is the workhorse of electronic data exchange in the clinical domain and arguably the most widely implemented standard for Healthcare in the world. The V2.xml defines the Extensible Markup Language (XML) encoding rules for traditional HL7 Version 2 message content. There have been seven releases of the Version 2.x Standard to date. HL7 Version 2 was also recently selected by the U.S Office of the National Coordinator for Health Information Technology as part of its initial set of standards, implementation specifications and certification criteria for EHR technology. Version 2.5 was also published as an international standard by ISO in June 2009 as the ISO/HL7 27931:2009 standard that is the subject of this works proposal as the departure point for knowledge acquisition. Acquisition from clinical notes is possible now by using the Web Services exposed in EHRs or flowing through Hubs like Mirth[32] or "traveling" in the different Regional, National or Supra-national HIE[33] networks currently under strong global dissemination.

5 Ontology Learning and Enrichment

The Biomedical Research Integrated Domain Group (BRIDG) Model is a collaborative effort engaging stakeholders from the CDISC[34] , the HL7 RCRIM TC[35,] the NCI[36] and

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[32] http://www.mirthcorp.com/

[33] Heath Information Exchange.

[34] Clinical Data Interchange Standards Consortium.

[35] Regulated Clinical Research Information Management Technical Committee.

[36] National Cancer Institute.

its caBIG®[37] , and the US FDA[38] . The BRIDG model is an instance of a DAM[39]. The goal of the BRIDG Model is to produce a shared view of the dynamic and static semantics for the domain of protocol-driven research and its associated regulatory artifacts. The BRIDG Model represents biomedical/clinical research. It was developed to provide an overarching model that could readily be understood by domain experts and would provide the basis for harmonization among standards within the clinical research domain and between biomedical/clinical research and Healthcare.

A DAM is a conceptual model used to depict the behavioral and static semantics of a domain of interest. A domain analysis model is used as reference material in development of information system interoperability specifications as well as design specifications of information system components. The preferred language for expression of a domain analysis model is UML[40] . A shared view of the various data structures and processes that define the BRIDG Model's domain-of-interest is essential in achieving the larger goal of semantic interoperability (SI) namely between systems (computable semantic interoperability (CSI)). Through the explicit definitions of shared semantics CSI is possible both within the BRIDG domain of-interest and between the BRIDG domain and other 'intersecting' domains (e.g. Public Health, Healthcare, etc.).

The goal of defining and representing the shared semantics (aka "meaning") of the BRIDG Model's domain-of-interest is achieved through the gathering and documenting the various business processes (dynamic semantics), data structures (static semantics), and relationships (static and dynamic semantics) that collectively are required to support CSI. The first formal release of BRIDG was published in June 2007. The BRIDG Model does bear a certain resemblance to the HL7 RIM. However, the overarching goal of the BRIDG Model is to represent domain-specific semantics in an implementation-independent fashion that is understandable to domain experts. This will deal with the problems illustrated in 2006 in [18] and is currently well addressed by the current 3.0.3 model version.

For our work to be fully contained we suggest an expansion of the work about Categorial Structure introduced in [14] into the ISO/HL7 27931:2009 but with the concrete OWL DL representation extracted from the BRIDG 3.0.3 Model.

6 Conclusion

We try to illustrate the possibility of taking advantage of the recent standardization and harmonization efforts and investigation in the related fields to seriously improve the capacity of ontology enrichment by automating the knowledge acquisition in the Health domain. Our proposal is based at one point in using the contents of the XML messages normalized to achieve data interoperability among health information systems and in the other end we suggest the use of the shared semantics model, fundamental to achieve broad acceptance and usage of the developed/enriched ontologies, recently developed

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[37] Cancer Biomedical Informatics Grid.
[38] Food and Drug Administration.
[39] Domain Analysis Model.
[40] Unifed Modeling Language.

by BRIDG. With these two focal points in mind we present and discuss which particularities are the more steep to handle and the recent contributions to their pragmatic resolution for the specific work in the knowledge sub-domain of Healthcare.

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Electrocardiogram Events Detection

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Abstract. This work aims to create a system of medical diagnosis of the Electrocardiogram (ECG). The events of the ECG are related with the functioning of the heart and different disorders of the heart functioning have their own ECG pattern allowing the connection between ECG patterns and cardiac disorders. For this purpose, we present here an algorithm that detects the P, QRS and T events of the ECG under MATLAB environment. The algorithm is based in two techniques. The search for picks and valleys and the search of event using a known patter and the correlation with ECG signal inside of a previously detected period. Finally the results are presented and discussed.

Keywords: ECG signal, P QRS and T events detection.

1 Introduction

The purpose of present project relays on a help system for medical diagnose of cardiac diseases using ECG exam. An algorithm to automatically detect the P, QRS and T events is presented here. The measure of the hit rate is also discussed.

The algorithm identifies the QRS points and the beginning, end and the maximum points of the P and T events.

The malfunction of the cardiac cycle due to changes in the heart morphology will modify the propagation of the repolarisation / depolarasation waves. Each heart disease makes standard changes in the signal of electrocardiogram. The changes mostly consist in missed events, ECG modifications and shortening or lengthening the ECG periods. Therefore, it is possible to connect the ECG signal and cardiac diseases.

1.1 The Heart

The heart is the most important organ of the human body. This organ is a central pump and has the mission of create blood pressure that provides oxygen and nutrients to cells.

The heart is a muscular organ the size of a fist with four chambers: right atrium (or auricle), left atrium, right ventricle and left ventricle [1], [2]. The two chambers upper and lower are called auricles and ventricles respectively. The wall that separates the heart into a right and left side are called septum [2]. The two sides of the heart are like a twin pumps. They are combined in a single organ but placed in series in the vascular system, where their connections have the purpose of separating the arterial from venous blood. The arterial blood is rich in oxygen and the venous blood in carbon dioxide [1].

M.M. Cruz-Cunha et al. (Eds.): CENTERIS 2011, Part III, CCIS 221, pp. 307–316, 2011.

To direct the flow of blood and prevent its backward movement the heart has four valves. The valves between the auricles and the ventricles are atrioventricular valves. The atrioventricular valve on the left side is called bicuspid or mitral and the atrioventricular valve on the right side is called tricuspid. Another two valves are the semilunar valves and they are between the ventricles and their attached vessels [2].

1.2 Cardiac Cycle

The human heart beats ceaselessly about 70 times a minute. The cardiac cycle begins with the simultaneous contraction of the auricles. Then, same happens with ventricles and the auricles and the ventricles relax. The phase of contraction the chambers is called systole and the phase of relax is called diastole. When the auricles are in diastole, the ventricles are in systole and vice versa.

When the auricles are in systole, the atrioventricular valves are open and the semilunar valves are open when the ventricles are in systole [2].

1.3 Control of Heartbeat

The intrinsic conduction system is responsible to the rhythmical contraction of the heart. There is a type of a cardiac muscle located in two regions of the heart. This muscle has muscular and nervous characteristics and is called nodal tissue. The two nodes in the heart are the sinoatrial node (or SA node) and the atrioventricular node (or AV node). The SA node is located in the upper dorsal wall of the right auricle and the AV node is located in the base of the right auricle very near the septum [1], [2].

The heart beat initiate with an exciting impulse sent by the sinoatrial node. This impulse causes the contraction of the auricles. The impulse reaches the atrioventricular node and this cause a slight delay allowing the auricles finish the contraction. The next step is the contraction of the ventricles. The impulse is now sent to the atrioventricular bundle (or AV bundle) and then immediately arrives to the numerous and smaller Purkinje fibers [2].

As explained, the sinoatrial node is very important because his responsible to keep the heartbeat regular. If the SA node fails the heart still beats by the impulses generated by the AV node. However, the rhythm is slower [2].

1.4 The Electrocardiogram

The electrical changes that occur during a cardiac cycle can be recorded by an ECG. The electrical impulse that travels through the heart is conducted by the ions present in the body fluids. These ions contained in the body fluids allow electrical changes in the cardiac cycle can be detected on the skin's surface [2].

To take a electrocardiogram exam it's necessary connect electrodes placed on the skin to an instrument (electrocardiograph) that detects the electrical changes in the heart.

When the sinoatrial node sends an impulse the atrial fibers generate an electrical change that is called the P wave, as depicted in Fig. 1. This wave provides information that the auricle are about to contract. When the ventricles are about to contract, we obtain the QRS complex. Finally, the relaxation of the ventricles is recorded and produces the T wave.

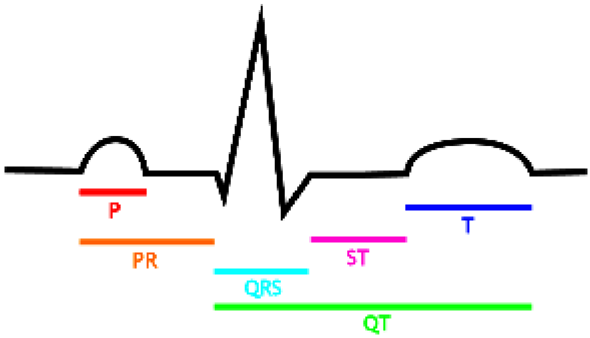

Fig. 1. Events of the electrocardiogram

2 Automatic Detection of Electrocardiogram Events

To rich the automatic system to diagnose cardiac diseases based on the ECG, the first step consist in developing an algorithm to automatically detect the events in a normal ECG.

For that purpose we are developing our algorithm under Matlab environment. The ECG signals used here were downloaded from the database *PhysioBank – physiologic signal archives for biomedical research* [3], and consist in *sel100m.mat* and *16265m.mat*.

The signal *sel100m.mat* has a sampling frequency of 250Hz and was used to detect the normal electrocardiogram events. The *16265m.mat* signal has a sampling frequency of 128Hz and as used to develop the algorithm and was also used to measure the hit rate performance of the algorithm.

2.1 Signal Preprocessing

The signal extracted from the database has duration of 12 hours. To not have to work with such a huge number of samples (1000000 samples), we used only one section of it with 10000 samples (Fig. 2). After loading the signal, we obtained the section as follows:

```
load('16265m_c.mat')
y=val(1,1:10000);
```

The ECG signal extracted on the surface of the skin's by the ECG has some oscillation due to electrical noise, small movements of the body and a contact not always perfect between the skin and the electrode. The noise in the signal is originated by the functioning of others organs and makes it harder to identify the electrocardiogram events. This oscillation consists in high frequency components of low energy producing small oscillations in the ECG signal. Thus, first at all the signal must be smoothed. For this, we used the moving average filter and a detrend filter. The smoothing process is very critical to remove all the picks and valleys others than

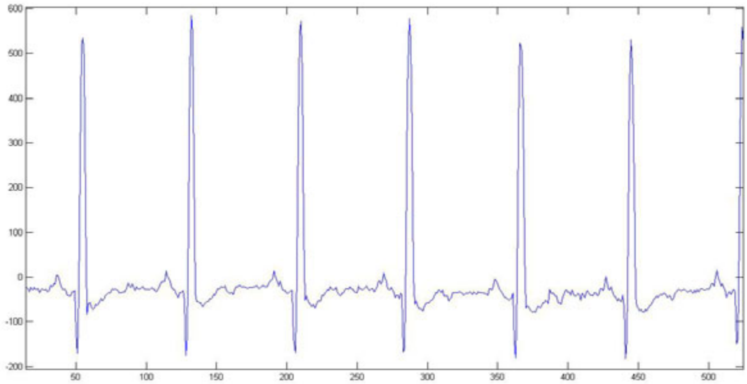

Fig. 2. Section of the first 520 samples of the signal *16265m.mat*

the expected P, QRS and T waves once the algorithm uses the search of picks and valleys starting from a known point.

The moving average filter consists in to recalculate the value of an experimental measurement using the average of points ahead and behind that measure. It's designated as a window length, N, the number of used points.

In the implementation of this filter it was necessary to determine the length of the section of signal used `L` using the command *length* and the central point of the window `N`, which is rounded to integer M using the *floor* command., as illustrated in next command lines.

```
L=length(s);
M=floor(N/2);
for i=1:M,
    m(i)=mean(s(1:i));
end
for i=1+M:L-M-1
    m(i)=mean(s(i-M:i+M));
end
for i=L-M:L,
    m(i)=mean(s(i-M:L));
end
```

The first and last *for* cycles carry on the moving average in the beginning and end of the signal where no M points are available for the moving average. The second for cycle implements de moving average over the middle points of the signal.

The detrend filter consists to remove a possible linear trend using the Fast Fourier Transform (FFT) processing [4].

In our signal we start smoothing the ECG signal with a moving average filter with length N=11, and using the detrend filter. An example of the smoothed signal is presented in Fig. 3.

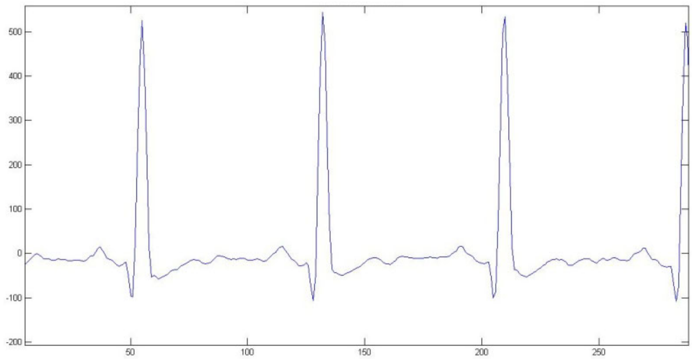

Fig. 3. Smoothed signal

2.2 Automatic Determination of Periods

The duration of cardiac cycle varies within patients and for the same patient it may have soft variations or even strong variations depending on the disease. The cardiac cycle can be measured as the duration between consecutive QRS complex.

To identify the duration of the cardiac cycle we used a technique based in the correlation coefficient. The correlation coefficient is the measure of a relationship between two vectors, this coefficient indicates the direction and strength between them [5].

The technique consists on the use of a vector of samples with the shape we are looking for in the signal and determine the successive correlation coefficients along the signal. This process results in a vector with the same length of the signal and with values very close to one in the positions in the signal with the searched shape.

The event, which was used for automatic detection of periods, was the vector corresponding to the QRS complex. We start by finding the maximum value and the rate at which this vector occur. Then a normalization of the amplitude took place. For points between the start signal and end signal subtracted from the vector length of less than one comparison was also carried out a normalization of the amplitude. Finally, the correlation was determined:

```
[u]=length(s);
v_qrs=s(52:57);
[p,ip]=max(v_qrs);
v=v_qrs/p;
L3=length(v_qrs);
for i=1:u-L3-1
    v2=s(i:i+L3-1);
    [p2,ip]=max(v2);
    v2=v2/p2;
    x=corrcoef(v,v2);
end
```

Figure 4 shows the signal and below the graph of the correlation. In this graph we can see that the values of correlation are between -1 and 1. We also found that when we are at the beginning of the QRS complex (Q point), the correlation is equal to 1, but with the increase of half the length of the vector of comparison gives the central position of the QRS complex.

The aim is to record the values of the indices in which there is a QRS complex in the vector.

As in several positions of the signal, the correlation is too high (close to one) and other situations may not even be equal to 1, the calculation of periods made itself a condition for the search of the QRS complex. Then the program only records the value of the correlation higher than 0.98. This value was experimentally obtained through the analysis of correlation graphs. Finally, the calculation of the period of the first cycle is performed.

```
[l]=length(xc);
j=1;
while i<l
      i=i+1;
      if xc(i)>0.98,
          pico_qrs(j)=i;
          j=j+1;
      end
end
P=pico_qrs(2)-pico_qrs(1)
```

The xc vector is the a segment of the correlation vector x where the QRS complex is expected as possible.

This method is very sensitive to the size of the vector used for the comparison, because if this is small will often be found along the same cycle and if you have a longer length will not be found in all cycles.

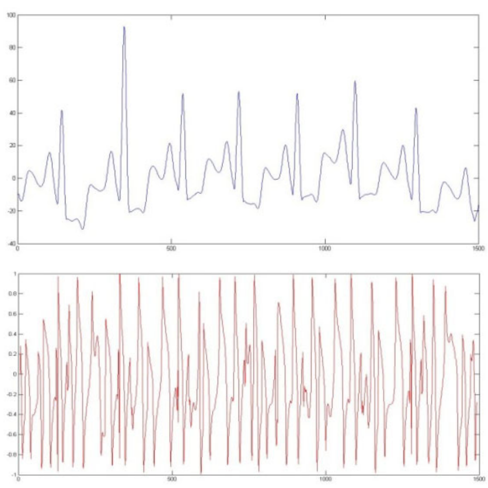

Fig. 4. Correlation of the QRS complex

2.3 Detection of ECG Events

The identification of the ECG events has based in the correlation coefficient technique, described before, and in the determination of picks and valleys.

The search of events has made using a segment of the original signal containing one period, plus about 20% of a period samples before and after. The periods were determined as described before. Therefore the algorithm described in this section is repeats along the periods of the ECG.

The algorithm began by creating a variable `j` which would be a sample reference inside the complete ECG signal. It is repositioned for a number of samples for the cycle being entirely represented. Once created a condition in which the detection of events occurring up to be an initial number to ensure that does not begin a cycle that is not full. The initial number was 170 samples.

We begin by numbering each cycle before the different complexes. We used a variable named `cycle` and were initiated at 0. Next, we selected a segment (`s3`) to search for the signal events of the ECG. This segment begins in the `j` position and has the length of the period plus 20%.

The next step was to detect the cycle period in which we were to experience the events of the ECG. For this, we seek the maximum value and its index in s3. If it is the first cycle, then the period is determined by the difference to the beginning of first QRS complex (144). However, if it is not the first cycle then the period shall be the index of maximum amplitude plus 50 (in order to guarantee one complete period). The end of the period will be recalculated later. The period, in seconds, is determined dividing the number of samples by the sampling frequency (Fa).

```
[pico,indp]=max(s3);
if ciclo==1,
    periodo(ciclo)=(indp+j-144);
else
    periodo(ciclo)=(indp+50);
end
periodo_s=periodo(ciclo)/Fa,
```

The first event to be detected was the point R. This point is exactly the maximum point previously calculated. Next step consist in adjust the end of our search area added to the index `j` to the R-point approximation of 90% over the period.

Behind the point R is the position of the P wave, more precisely the end of P wave. The only way found to make its detection was by correlation technique. It was carried out in exactly the same way as explained earlier, using and adequate vector for comparison. Within the specified condition we just have give the legal position for the end of P point, that is between the start of the cardiac cycle and the point R. We have to add the variable `j`, because this variable is the position inside the entire signal.

```
[pic3,indmax3]=max(xc3(0+j-1:pont_R+j-1));
fim_P=indmax3+3
```

The correlation procedure was also used to find the Q point, and the search area (legal zone) goes from the end of P wave to the R point. The point that marks the beginning of the T wave has also found by the correlation procedure with the legal zone beginning at the S point to the result of the value of the period plus a number that allows us to look without that section of the signal ends.

For the other ECG events, the procedure was the search of picks and valleys.

Therefore, we can detect an event through the end of an ascent or a descent. Thus, with reference to the end of the P wave signal backwards we found a rise and at the end of the rise is the maximum of the P wave.

On the other way if the point is higher than previous one, and this was repeated some points, we are witnessing a rise. Obviously one begins to decrement in the section on the end of the P wave.

```
i=fim_P-1;
while ~((s2(i-3)<s2(i-2))&&(s2(i-2)<s2(i-1))&&(s2(i-
        1)<s2(i))),
     i=i-1;
end
max_P=i
```

This method of ascent is also used to detect the maximum of the T wave. To do this we must move forward from the point R and started looking for him after the start of the T wave. But in place of decrements will be increments.

```
i=max_T+1;
while ~((s2(i+2)>s2(i+1))&&(s2(i+1)>s2(i))),
     i=i+1;
end
fim_T=i;
```

The beginning of the P wave was determined by searching for the valley on the left of the maximum of P wave.

```
i=max_P-1;
while ~((s2(i-2)>s2(i-1))&&(s2(i-1)>s2(i))),
     i=i-1;
end
in_P=i
```

This procedure is used to detect the S and the end of the T wave, with the difference that we start from R point and maximum T, respectively.

To advance to the next cycle, only `j` will assume the value of previous `j` plus the R point and added to a safety margin of 50 samples.

3 Results

In fig. 5 all points of interest marked in a single cycle are displayed. In order to measure the efficiency of the algorithm, the hit rate for the all events and points, given by eq. 2, was determined over a 100 cardiac cycles. In table 1, we can see the hit rate for each point of the ECG.

$$Hit\ Rate = {}^{number\ of\ hits}/_{number\ of\ periods} \quad (2)$$

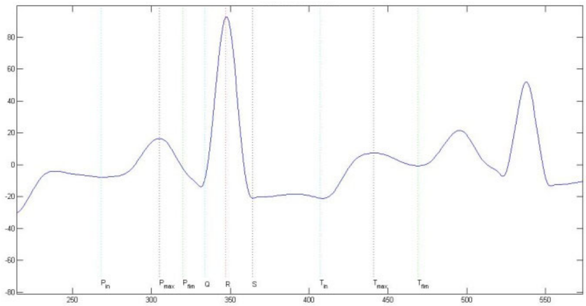

Fig. 5. One cycle of the ECG events

Table 1. Hit rate in %, for each point of the ECG

Point	Begin. of P	Max P	End of P	Q Point	R Point	S Point	Begin. of T	Max T	End of T
Hit Rate	56	56	56	66	90	90	41	36	36

These hit rates can be improved with better filtering of noise, because in some cardiac cycles smoothing was high, which complicates the detection of some points of the ECG, including the P and T wave.

4 Conclusions

An algorithm to determine the events of a normal ECG is presented as a part of a medical system for suggest the diagnosis of cardiac diseases over the ECG.

The algorithm start by filtering the ECG signal in order to smooth the signal using a moving average and a detrend filters. This smoothing process is very sensitive to the performance of the following algorithm, because of the picks and valleys technique used for search of several point.

Than the periods has determined by searching the QRS complex using a new proposed technique based in the correlation coefficient.

The reference point was the point R, from this point was determined the Q point and the end of P wave. Through the end of P wave we find the maximum point and then the beginning of the P wave. These points were calculated by searching the picks and valleys. The following points were determined also by the search of picks and valleys and were determined in the following order: S point, the beginning, the maximum and the end of the T wave.

This algorithm can give good results if the smoothing process is adequate, as presented in fig. 5, but final results presented in table 1 showed that more robust method should be used or the smoothing process should be improved.

In the future a wavelet technique to search the events should be implemented.

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Improving the Elder Care's Wireless Sensor Network Fall Detection System Using Logistic Regression

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Abstract. The world's population is aging; we are already facing many socioeconomic challenges directly related to this problem. These challenges will only tend to grow as time passes. If viable solutions are not found in time, these challenges will become unbearable as the elderly population surpasses the younger population.

One of the more serious health problems faced by the elderly are falls that are not succored fast enough. In this paper we discuss the motivations behind our work and specially our focus on fall detection.

We will also present the new Elder Care's fall detection system, resultant of our research in the area of statistical regression.

Keywords: health monitoring, logistic regression, fall detection, wireless sensor network, body area network, aging.

1 Introduction

The Elder Care project was started in 2009 [1], with the main focus on helping to solve some of the growing problems related with the aging society we live in. This project intends to have a range of action as wide as possible, distinguishing itself from other similar projects by providing not only infrastructure and health monitoring support but also by implementing solutions to avoid social abandonment.

To accomplish these objectives, Elder Care was divided in smaller projects [2], each one of them with a specific objective. One of them, the Body Monitor project, is responsible for developing a network of wirelessly connected body sensors, capable of constant monitoring the elderly and that in case of alert is capable of communicating with the Elder Care's control center. If an alert situation occurs in the elderly's house, the communication is made via the home

M.M. Cruz-Cunha et al. (Eds.): CENTERIS 2011, Part III, CCIS 221, pp. 317–326, 2011.

wireless connection, and if in the exterior using a GSM connection. The system is also easily used by the elderly without needing the help of a technician.

In order to guaranty the usability component of this project, a scalable architecture has been developed [3]. This architecture enables the easy addition of new sensors to the system, without the need for it to restart, or any reconfiguration to the network having to be made.

In regard to the data acquisition component, most types of data can be easily acquired using existing sensors. For example, the elderly's position can be obtained using a GPS (when not at home) and his heart rate using a heart rate monitor. This is due to fact that these types of data can be obtained using small sampling rates and the lower the sampling rate the longer the battery life. Since this system requires as little maintenance as possible, a small battery life is not acceptable.

On the other hand, to be able to undoubtedly distinguish falls from activities of daily living (ADL) a high sampling rate is necessary, if not, it becomes difficult to distinguish a fall from an action like a more strong sit. Under these circumstances, some accuracy compromises must be made, to attain a usable battery life. The solution being present in this article enables for precise fall detection while using a low sampling rate.

In the following sections, we will present the work being done in order to develop a viable fall detection system. To do so we will start by explaining the motivation behind the Elder Care project, especially the reasons for us to focus on fall detection. After, we will explain what exactly is a network of wirelessly connected sensors, its story, its medical uses and introduce the existing Elder Care architecture. We will continue by introducing the concept of logistic regression in order to attain more precise fall detections. Following this introduction, the results of using logistic regression will be presented and explained. A new fall detection architecture, already using the logistic regression will afterwards be explained. Finally, we will discuss the aforementioned results and describe our future work.

2 Motivation

At a socioeconomic level, one of the major challenges of the century is that the world's population is aging. This is most visible in the developed countries, where the increase in life expectancy associated with the drastic decrease in birth rates has led to a rapidly aging population. In developing countries, while the birth rate still is not a problem, the elderly population has been increasing since the 1990s. The declining birth rates in developed countries, associated with increased life expectancy in developing countries, has led to a point where for the first time in history, the percentage of the world population with over 65 years is larger than the population under the age of 5 years [4].

The European Union countries are between the most affected. In a 2008 study from Eurostat it is presented data, which indicate that the percentage of population over 65 years will pass from 17.1% to 30.0% in the period between 2008 and 2060. In addition, the population will only continue to grow until 2035, from there after it is expected that the population begins to decrease [5].

Economically, the aging of the population brings major problems. These problems include a spending increase on pensions, health care and continuing care, but also a decrease in the number of active people. In Europe, this decrease is expected to be from a ratio of close to 3 workers for each pensioner in 2005, to 1.5 workers for each pensioner in 2050 [6].

Through the use of the technology developed by the Elder Care workgroup [7], it is expected to be possible to greatly reduce the costs linked to both the early admission in nursing homes, as well as, the medical costs of accident related hospitalizations.

The purposed system will avoid admission of an elderly person who retains his mental abilities and that would only be placed in a nursing home to have constant monitoring, as this monitoring will be done by sensors placed on the elderly's body. The fact that the elderlies are being monitored constantly will bring benefits not only to those who stay at home but also to those who for reasons of inability to live alone have to stay at nursing homes. The monitoring that is done today cannot be compared with the one that can be achieved through the use of physical sensors. Not only can they detect accidents faster, but also help diagnose health problems.

The great importance that is given in this project to the detection of falls comes from that fact that the World Health Organization has established that 30% of the population over the age 65 falls at least once each year, this percentage is even higher in the group of 80 and over, where it reaches 50% [8]. This falls are the main reason for injuries that need hospitalization, and also the primary cause of injury-related deaths. Still, it is important to distinguish falls when the elderly is with someone, from those when the elderly is by himself resulting in a situation where he is unable to call for help, staying long periods of time without the necessary medical help. In some cases, the time the elderly stays without aid is so long that it inevitably leads to the death of the elderly. A typical case scenario that leads to a situation like that described before is the elderly having a stroke. In cases like this, the medical aid time window is very small and the elderly becomes unable of requesting help.

3 Wireless Sensor Network Evolution

The Wireless Sensor Network (WSN) technology has come a long way since it was first used in 1967 during the Vietnam War. It was developed under the project Igloo White [9] with the purpose of deploying a wireless network of seismic and acoustic sensors in the Ho Chi Minh trail. Like many other technologies that were developed with the intention of arming human lives, we are now using WSN to save them.

With the emergence of WSNs, and the rapid growth of physiological sensor technology, scientists from various fields of study sought to adapt sensor networks for the purposes of health monitoring applications. In 2006, Guang-Zhong

Yang coined the term Body Sensor Network, or BSN, to refer to that particular application of WSNs [10]. Body Area Network (BAN) technology is a natural refinement of that concept, providing more flexibility for a broader set of applications (though still focusing the most on medical applications). BANs, as the name suggests, are networks of computing entities that have the distinctive characteristic of being physically linked to a user's close proximity.

As aforementioned, BANs are a generalization of BSNs, which were conceived for medicinal purposes. The word "body" present in both terms obviates the technologies' potential for diagnostic, monitoring and health care services, and it is in fact the industry on which most of the BAN research and development focuses on. There are numerous projects of this nature, and the systems they propose tend to fall under one of two categories [11]:

- managed body sensor networks - systems where the third party (e.g. a health care specialist) makes decisions and interventions based on the data collected by a number of BSNs.
- autonomous body sensor networks - in which a more proactive approach is taken, giving the sensors enough intelligence to control actuators that allow the BSN to affect the users body (e.g. automatically injecting insulin through a pump as required).

Enabling remote monitoring of patients has distinct advantages, like reducing internment and aftercare costs, as well as providing speedier delivery of preventive and emergency care, with little to no attention required from the patient. The patient quality of life can also be improved by avoiding confinement to the proximity of non-portable medical monitoring equipment.

We have already started working on our own autonomous body sensor network. The main initial focus of our work has been on implementing a scalable architecture, this enables that in the future other types of sensors, not only those chosen for the fall detection, can be easily added to the system. The initial architecture consists in a set of sensor nodes positioned on a human body, collecting data and detecting abnormalities. The information is afterwards sent to a central sensor node (nominated by coordinator). This coordinator then sends information to a base station or a mobile phone. The base station or mobile phone manage alerts sent according to the occurred events. As soon as the task group 6 of the IEEE work group 802.15 [12] finishes its specification for BAN, we intend to make the necessary changes to our own architecture in order to comply with it.

4 Logistic Regression

The logistic regression model is part of a class of statistical models known as generalized linear models (GLM). GLM were first presented in 1972 by Nelder and Wedderburn in [13], and a more in depth description was later given by McCullagh and Nelder in [14].

The logistic regression model is very similar to the more common linear regression model. The main difference is that while the response variable of linear regression is typically continuous, the one from logistic regression is binary or at least categorical [15].

Like in several others situations (experiment planning, clinical trials, epidemiology studies, observational studies), the Elder Care's response variables [16] are dichotomous. Under these circumstances, is more appropriate to use a linear predictor (logit) defined as

$$\ln\left(\frac{\pi}{1-\pi}\right) = \beta_0 + \beta_1 x_1 + ... + \beta_p x_p \tag{1}$$

where

$$\pi = P\left(Y = 1\right). \tag{2}$$

In the Fall Detection context, the response variable Y should be 1 if a fall occurs and 0 otherwise. Each x_i represents a movement parameter collected by the sensors placed on the elder.

5 Tests and Results

In a previous work, done by Elder Care's research group [17], it was concluded that relaying solely on the acceleration to distinguish a fall from an ADL, was not a very precise solution. This was more noticeable, when comparing the data from an actual fall to a rougher sit action. Based on the study of the previous works done in the area of fall detection, especially those from A. K. Bourke [18] and G. Wu [19], it was also concluded that the best solution was to use velocity instead acceleration.

The reason we decided not to use velocity, comes from the fact that it would have a big impact in terms of battery life. While to calculate the persons acceleration it is only necessary to use the acceleration data from each axis at a given time, and then calculate the resultant acceleration without the gravitational component, using the formula

$$a = \sqrt{x^2 + y^2 + z^2} - 1. \tag{3}$$

To calculate the velocity it is necessary not only to have the acceleration of that instant, but also to constantly integrate it to obtain velocity. Disregarding the problems brought to the battery life by these additional calculations, there is still the necessity to compensate the inaccuracy problem of tracking movement using only a tri-axial accelerometer. The proposed solution [20] relies on using a high sampling rate followed by the applications of different filters, a similar solution was implemented in [21].

In order to find a solution that did not rely on using velocity, it was decided to record and study the data from a series of both fall tests and sit action tests. The sensor board used during this tests was the Intel Mote2, that is able to achieve processing speeds of up to 520MHz [22] and the accelerometer used was the one present on the Crossbow iMote2 sensor board, the ST Micro LIS3L02DQ [23], a picture of the Intel Mote 2 can be analyzed in Fig. 1.

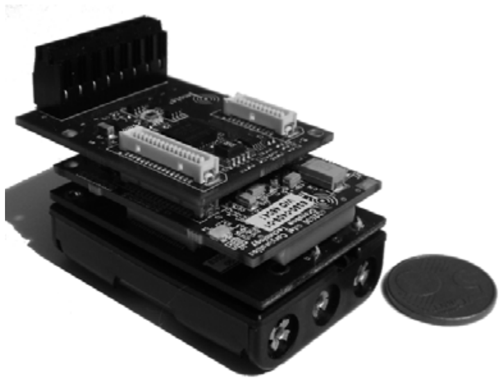

Fig. 1. Intel Mote 2 with the sensor board (top) and the battery board (bottom)

For the fall component of the study we decided to simulate lateral (both left and right), back, frontal and vertical falls. In order to gather the required data, without the existence of other variables involved other that the ones we wanted to record, it was decided not to use human subjects. To study a vertical fall it was used a 5kg box with the sensor coupled to it. This box was then dropped from a height of one meter. To test a fall where there were more axis involved that just the vertical axis, was design a system that would create falls with a consistent arc trajectory. This system consists of two wood boards, one of them with the size of 1,7m to simulate the height of a human being, the size of the other board is irrelevant as it only serves to fixate the system to the ground; the one representing the human is placed upright and are both connected on the extremities by a hinge. For the fall sit actions tests, as there is no other way to recreate the human action of siting down, human volunteers were used. The sit action tests were conducted by both male and female volunteers and the test was conducted in both a chair and a couch.

The resulting data consisted of 150 fall tests (30 for each direction) and 110 sit action tests. The tests were preliminarily studied using in-house developed software and four fall tests were removed as they were considered to have recording errors. Table 1 contains the data from the preliminary study, still only using acceleration.

As can be seen on the previous table, the minimum acceleration value obtained from the fall tests is smaller than the maximum value obtained on the sit actions. In case a detection algorithm solely based on acceleration was used, 92 of this

Table 1. Table containing the summary of the recorded data

Type	Number of Tests	Max Acceleration	Min Acceleration
Fall	146	2.190	0.938
Sit	110	2.024	0.154

fall actions would be considered actual falls, giving it only a 16% of precision on this type of situations. The data was then converted and exported to be used by the statistical analysis software IBM SPSS [24].

After an iterative process, where one fall test and five sit tests were removed due to detected errors, we came to the results found in table 2.

Table 2. Final results of the logistic regression study

Type	Correct	Wrong	Percentage correct
Fall	143	2	98.6
Sit	102	3	97.1
Total	245	5	98.0

Having considered this to be good variable set, it was now necessary to extract each variable value to be used on the logistic regression equation. Table 3 contains each variable and its corresponding value.

Table 3. Coefficients to be used on the logistic regression equation

	β_i
Axis X	11.905
Axis Y	12.622
Axis Z	4.081
Resultant Ace	21.556
Constant	5.479

The estimated logit is then

$$\ln\left(\frac{\hat{\pi}}{1-\hat{\pi}}\right) = 5.479 + 11.905X + 12.622Y + 4.081Z + 21.556Ace \tag{4}$$

and the probability can be estimated by

$$\hat{\pi} = \frac{e^{11.905X+12.622Y+4.081Z+21.556Ace}}{0.0041735 + e^{11.905X+12.622Y+4.081Z+21.556Ace}}. \tag{5}$$

An example of this equation being used to calculate the probability of both an actual fall and a sit action that would normally be detected as a fall, can be seen on table 4. While both have very similar resultant accelerations and module values of component acceleration, one is clearly detected as a fall and the other is clearly detected as being a sit action.

Table 4. Example of how the probability of a fall can be estimated

Type	Axis X	Axis Y	Axis Z	Resultant Ace	$\hat{\pi}$
Fall	1.652	2.088	-.792	1.778	1
Sit	-1.593	-2.089	-.778	1.741	1.40×10^{-26}

6 Proposed Architecture

After studying the logistic regression results and analyzing the possible impact of implementing the algorithm on the wireless module itself. We decided that it would bring more advantages if the logit was implemented on a new module of the Elder Care's Central System.

In the new proposed architecture, the WSN detects possible falls using the solely the acceleration and with a small sampling rate of 20hz. In the central system, the data is then be processed and depending on the fall probability returned by the logit a different type of response is given.

- If the returned probability is 100%, then the central system immediately contacts the emergency medical services so that the elderly can receive medical support as fast as possible.
- In case the percentage is less than 100% but still higher than 0% a more restrained action is taken, a operator first tries to contact the elderly, followed by is the close relatives. If both these actions fail, the emergency services would then be contacted.
- Finally if the system reported 0% probability of accident, not only the elderly and the close relatives would be contacted but any of know relatives so that a personal verification could be made before contacting any type of medical service.

While the precision of the system is under 100% some type of verification should be made even when the system reports a 0% chance of being a fall. What we

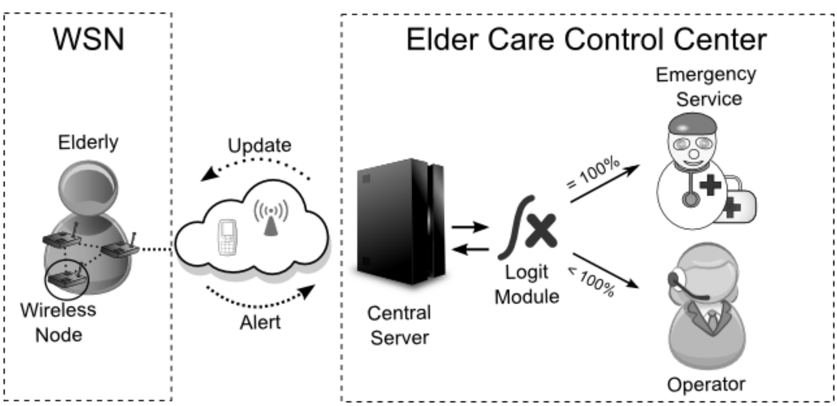

Fig. 2. The New Proposed Architecture

intend to do, is to allow the system to learn with each new alert, instead of relying solely on the existing tests. The system should continue to reevaluate the logit formula in order to better the system's precision.

Figure 2 contains a diagram of this new architecture.

7 Conclusion

With this work we hope to have shown how important it is to develop a viable solution for elderly remote monitoring. In our opinion, we have also introduced a good alternative to the existing fall detection algorithm. By using logistic regression, it is possible to make almost as precise fall detection as with velocity while requiring less processing.

One big advantage of logistic regression, is that it is not hardware or data dependent so its use is not exclusive to this particular solution. If the use of velocity becomes a viable solution, the new data can be easily added to our existing equation, making it an even more precise solution.

Also there is no real reason why this solution should not be used, as it does not bring any additional computational power to the system's normal running. As this solution only uses existing data, the new equation is run server side. So, instead of avoiding the sending of the fall alert, it is used to calculate the probability of the fall. Therefore, becoming extra decision information for the responsible of the control center to take in account before calling the actual alert.

In this article, we also gave a big emphasis on distinguishing false positives, they can have and adverse effect on the correct function of the system by discrediting its precision, leading to a situation where a real positive may be ignored.

8 Future Work

Our WSN module is expected to be finished soon, so the next stage of this project will consist on porting the newly developed system to the new module. This new module has newer and more precise sensors so we expect to be able to obtain even better results. These results will enable us to improve the algorithm so that the 1.4% false negatives can be corrected.

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Application of Statistical Methods to Improve an Acceleration Based Algorithm

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Abstract. Falls are the leading reason for death related accidents in people over 65 years old. Concerning this situation, it is necessary to develop a viable way of detecting these falls as fast as possible, so that medical assistance can be provided within useful time.

In order for a system of this kind to work correctly, it must have a low percentage of false positives and a good autonomy. In this paper we present the research done in order to improve an existing acceleration based algorithm, which despite being inaccurate is however highly energy efficient. The study of its improvement was done resorting to the use of cluster analysis and logistic regression.

The resulting algorithm distinguishes itself by being, at the same time, very accurate and having low energy consumption.

Keywords: health monitoring, logistic regression, fall detection, cluster analysis, wireless sensor network, aging.

1 Introduction

Today's society faces many challenges, being one of the most worrying the increase in the percentage of the elderly population. In a 2008 study from Eurostat [1], it is presented data which indicates that, in Europe, the percentage of population over 65 years will rise from 17.1% to 30.0%, in the period between 2008 and 2060.

Problems related to an aging population are both at a social and economic level. Knowing the duality of this problem, the Elder Care project [2] was started in 2009 with the objective of applying the new technologies of the Information Age to help improve the quality of life for elderly. These objectives spread from more social levels, like reducing the social exclusion that affects a big part of the elderly population [3], to some more economic and health care related problems,

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like enabling the elderly to continue living in their own homes, while still having the same health monitorization they would have if they were living in a nursing home.

In order to accomplish these distinct objectives, the Elder Care project was divided in various workgroups. The one responsible by the work being presented in this paper is the Body Monitor workgroup. This workgroup is doing research in the area of Wireless Sensor Networks (WSN) applied to health care, with the objective of developing a network of sensors, capable of monitoring many aspects of the daily living of its user.

A big problem that has been faced, is how to precisely detect and, at the same time, distinguish a fall from an activity of the daily living (ADL). As we will be later show in this paper, if the sensory data from the network is not correctly processed, false alerts can be triggered by some types of ADL. A system with this kind of problem would end up being almost as ineffective as no system at all. Like in the children's tale, where the young shepherd yelled wolf where there was none, then when the wolf did actually attack, the shepherd ended up losing all his sheep. This system would also perish from this same problem, because when a fall did actually occur it would be treated with disbelief and might even be completely ignored. So, to be able to avoid this type of situation without compromising the actual usability of our WSN, it was decided to study the effects of using statistical methods like cluster analysis [4] and logistic regression [5].

This paper will start by introducing the concept of fall detection and describing some previous work done in this area. It will continue by explaining the testing system used to acquire the necessary data. Afterwards, both the cluster analysis and the logistic regression approaches will be described, followed by the conclusions taken from this study and ending with the description of the steps being taken next by this workgroup.

2 Fall Detection

One of the first big steps, towards an actual autonomous fall detection system was taken on the early '90s by Lord and Calvin [6]. In this study, it was shown, that through the study of movement of the human body during a fall, it would be possible to develop a sensor network capable of detecting those same types of falls.

Over the years and with the development of new technology areas, newer and different ideas on how to more precisely detect fall have emerged. In 2000, using video image processing, Ge Wu [7] studied multiple ADLs and compared them to falls. This study has shown that the only ADLs that could be mistaken for falls were sit down actions. Ge Wu was also able to not only correctly detect falls, but also to distinguish them from ADLs. This work was later improved in a 2008 study by Alan K. Bourke [8]. In this study, video image processing was used to train a tri-axial accelerometer system and was proven that by resorting to vertical velocity alone, it was possible to detect and distinguish a fall with 100% certainty.

Even though there might already exist solutions with perfect precision, these solutions are still far from ideal. The video image processing solution relies on data being acquired, using a device placed outside the system being monitored. The accelerometer solution requires a big sampling rate and the use of multiple filters in order to correctly calculate velocity. While using video image processing, it is relatively easy to measure the body's velocity during the fall, by measuring the movement during each frame. In a system that relies on data being acquired by sensors placed on the user's body, what is commonly obtained is the acceleration. Also, this acceleration is acquired through sampling so it is prone to errors. These errors must be mitigated through the use of big sampling rates or the use additional sensors, like gyroscopes and magnetometers [9]. Finally, to precisely obtain velocity it is necessary to constantly integrate the corrected acceleration data. Using this process with the existing equipment, would create a very energy constrained solution, like we observed in a previous study we conducted [10].

3 Tests and Control Results

In order to develop a system with accuracy close to that obtained by using a high sampling rate, it was first necessary to study the data acquired from an accelerometer during both falls and different ADLs. The sampling rate we decided to use was 20Hz, less than half that used both in [8] and [11].

The WSN module chosen for this research was the Intel Mote2 platform [12]. This network module has a scalar processor that can achieve processing speeds from 14 MHz up to 520MHz. The accelerometer used was the one present on the Crossbow iMote2 sensor board, the ST Micro LIS3L02DQ[13].

To be able to record multiple tests without having too many external variables and random results, it was decided not to use any human subjects during the initial fall data acquisition. For the vertical fall study, it was used a 5kg box with the sensor coupled to it, this box was then dropped from a height of one meter. To test a fall where there were more axis involved than just the vertical axis, was design a system that would create falls with a consistent arc trajectory. This system consists of two wood boards, one of them with the size of 1,7m to simulate the height of a human being, the size of the other board is irrelevant as it only serves to fixate the system to the ground; the one representing the human is placed upright and are both connected on the extremities by a hinge. During the actual test the sensor was placed in one of two positions, at a high of 0,85m to simulate the height of the hip and at 1,45m to simulate the height of the shoulder.

As it was aforementioned, Ge Wu work shown that the type of ADL more prone to values similar to a fall are the sit down actions. During the testing of the equipment itself, this was proven to be even more evident when relying solely on accelerometers. ADLs like normal walking, running, going up and down stairs did not manifest big changes in acceleration. Sit down actions, especially rougher ones, on the other hand, presented big spikes in acceleration. Due to this fact, it was decided to center the attention on recording different types of sit actions. As there is no other way to recreate the human action of siting down, human volunteers were used. The sit action tests were conducted by both male and female volunteers and the tests were conducted in both a chair and a couch.

During the testing phase 150 fall tests (30 for each direction plus vertical) and 110 sit action tests were conducted. After a preliminary analyze of the data had been done, four fall tests were removed due to recoding errors.

To test the precision and improvement brought by the use of statistical models, the resultant acceleration without the gravitational component was first calculated for each instant, using the formula

$$a = \sqrt{x^2 + y^2 + z^2} - 1. \quad (1)$$

From this new data set, was extracted the highest value of each test run and table 1was obtained.

Table 1. Table containing the summary of the recorded data

Type	Number of Tests	Max Acceleration	Min Acceleration
Fall	146	2.190	0.938
Sit	110	2.024	0.154

As can be seen on table 1, the minimum acceleration value obtained from the fall tests is smaller than the maximum value obtained on the sit actions. So if only the raw acceleration was to be used in order to distinguish a fall from an ADL, 92 of this fall actions would be considered actual falls. Using only acceleration would than give a 16% precision.

4 Cluster Analysis for Fall Detection

Since we are interested in developing a fall detection system, we need to separate our data into two classes of objects; one meaning that a fall occurred and another stating that a fall did not occur. After that, knowing ours groups, we are interested in assigning a new item to one of the two classes. Thereby, a nonhierarchical clustering method, such as K-means method, could be applied. Cluster analysis is a technique in that no assumptions are made concerning the group structure.

We could start with a "learning" sample, which will be divided into two regions, R1 and R2 such that if a new observation falls in R1 it will be allocated to group "a fall occur" and if it falls in R2, we allocate it to "a fall did not occur".

k-means algorithm [4] is composed of three steps:

1. partition the items into 2 initial clusters ($k = 2$);
2. assigning an item to the cluster whose centroid (mean) is nearest. Recalculate the centroid for the cluster receiving the new item and for the cluster losing the item;
3. repeat step 2 until no more assignments take place.

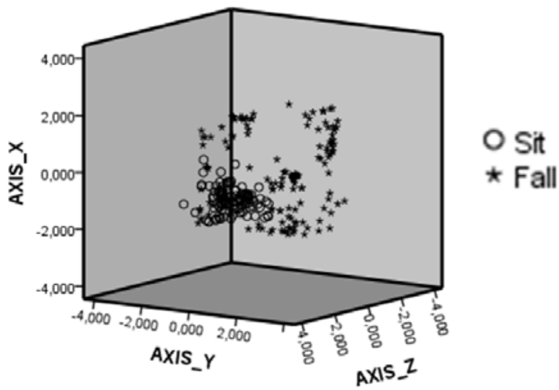

Fig. 1. Data over X, Y and Z

The test data was exported to be used by the statistical analysis software PASW Statistics (previous SPSS) [14].

Exploring our data, we can see the data in a 3D plot, Fig. 1, along X, Y and Z axes.

We can also notice that it will be difficult to group the observations into two clusters, since the observations "sit" and "fall" are strongly mixed. Running a k-means method with two clusters we obtain the final centers, see table 2:

Table 2. Final cluster centers

	Cluster	
	1	2
AXIS_X	-1,282	680
AXIS_Y	-1,206	1,506
AXIS_Z	-0,632	0,132
ACCEL	1,331	1,698

From the ANOVA table 3, we can see that the most significant variables to clusters definition are Y and X, following by Acceleration and Z, at last, because greater values of F statistics shows the most significant variables in analysis.

Comparing the cluster analysis results with our data, table 4, we can see that there are many misclassifications, and they all report to falls that were considered as sits.

As cluster analysis provides that X, Y and Accel are the most significant variables in clustering, we can see in Fig.2, based on them, the results and misclassifications.

Table 3. ANOVA table

ANOVA						
	Cluster		Error			
	Mean Square	df	Mean Square	df	F	Sig
AXIS_X	211,866	1	0,908	254	233,317	0,000
AXIS_Y	404,597	1	0,791	254	511,647	0,000
AXIS_Z	32,096	1	1,176	254	27,298	0,000
ACCEL	7,400	1	0,108	254	68,296	0,000

Table 4. Results with k-means cluster analysis

Type	Data	Correct	Wrong	Percentage correct
Fall	146	80	66	54,8%
Sit	110	110	0	100%
Total	256	190	66	74,2

5 Logistic Regression

The logistic regression model is part of a class of statistical models known as generalized linear models (GLM)[5]. The logistic regression model is very similar to the more common linear regression model. The main difference is that while the response variable of linear regression is typically continuous, the one from logistic regression is binary or at least categorical [15].

Like in several others situations (experiment planning, clinical trials, epidemiology studies, observational studies), the Elder Care's response variables [16] are dichotomous. Under these circumstances, is more appropriate to use a linear predictor (logit) defined as

$$\ln\left(\frac{\pi}{1-\pi}\right) = \beta_0 + \beta_1 x_1 + ... + \beta_p x_p \quad (2)$$

where

$$\pi = P\left(Y = 1\right). \quad (3)$$

In the fall detection context, the response variable Y should be 1 if a fall occurs and 0 otherwise. Each x_i represents a movement variable collected by the sensors placed on the elder.

So the test data was again imported into PASW Statistics, like before the first test was only run using the individual acceleration values. The first logistic regression results are shown in table 5.

These were already better results than those obtained using cluster regression, the next step consisted on adding the resultant acceleration to the study and the results are on table 6.

These results were clearly better than both the control and the cluster analysis ones. But there was still room for improvement, one thing that was already

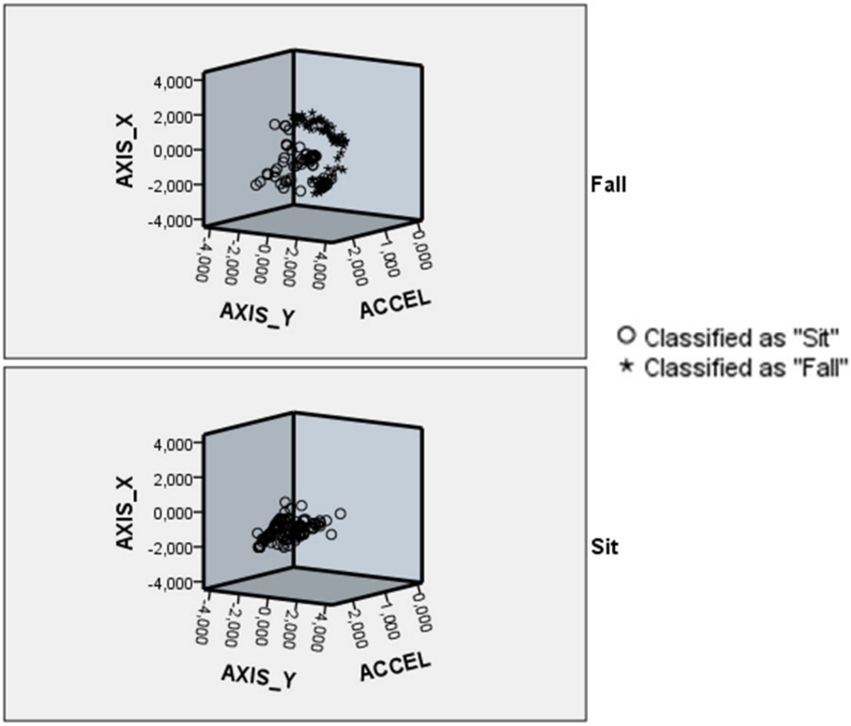

Fig. 2. Misclassifications with cluster analysis

noticed during the preliminary study was that many of the tests had small recording mistakes. These mistakes were expectable as the equipment used is just a prototype so the sensors and batteries were not strongly secure to the processor board, leading to small data losses.

So to better identify the data incongruities we decided to use the difference in beta values (DfBeta) [17] obtained as a sub product of the logistic regression analyzes. A box plot graph was then created using the DfBetas and two influential observations were identified. The analyses' process was repeated, this time without the newly identified influential observations and the results in table 7 were obtained.

Table 5. Logistic Regression using only the acceleration from the three axis

Type	Correct	Wrong	Percentage correct
Fall	127	19	87.0
Sit	104	6	94.5
Total	243	13	90.2

Table 6. Logistic Regression using the resultant acceleration and the acceleration from all three axis

Type	Correct	Wrong	Percentage correct
Fall	138	8	94.5
Sit	105	5	95.5
Total	243	13	94.9

Table 7. Logistic Regression without the first detected influential observations

Type	Correct	Wrong	Percentage correct
Fall	142	4	97.3
Sit	103	5	95.4
Total	245	9	96.5

Table 8. Final results of the logistic regression study

Type	Correct	Wrong	Percentage correct
Fall	143	2	98.6
Sit	102	3	97.1
Total	245	5	98.0

Table 9. Coefficients to be used on the logistic regression equation

	β_i
Axis X	11.905
Axis Y	12.622
Axis Z	4.081
Resultant Ace	21.556
Constant	5.479

The DfBetas were again studied and another four tests were considered mistakes. Table 8 contains the final results since the study of the following DfBetas did not reveal any new influential observations.

Having considered this to be the final variable set, it was now necessary to extract each variable value to be used on the logistic regression equation. Table 9 contains each variable and its corresponding value.

The estimated logit is then

$$\ln\left(\frac{\hat{\pi}}{1-\hat{\pi}}\right) = 5.479 + 11.905X + 12.622Y + 4.081Z + 21.556Ace \tag{4}$$

and the fall can be estimated by

$$\hat{\pi} = \frac{e^{11.905X+12.622Y+4.081Z+21.556Ace}}{0.0041735 + e^{11.905X+12.622Y+4.081Z+21.556Ace}}. \tag{5}$$

6 Conclusions

In this article we showed how hard it can be to distinguish an actual fall from an ADL. While there are already proven solutions, all still have their inherent problems, like being constrained to a specific location or having energy limitations.

Our study of cluster analysis proved to be a bad choice for fall detection. While it was able to correctly distinguish ADLs, it failed to detect several falls. However, its results are still important, as they helped understand how entangled the different results are and the problems that this brings to the problem being studied.

On the other hand, the use of logistic regression proved to be a good bet. Its inclusion in the Elder Care project brought different advantages, the most obvious one being the high precision in distinguishing falls from ADLs. This enables us to send alerts with different degrees of urgency, in this way reducing the risk of discrediting the system by sending urgent alerts where there was no accident. Another improvement logistic regression brings to the system, is in terms of battery saving. The logit can be processed in the central system; only requiring the data from the actual instant the alert was produced. Also, to be able to create the alert the system only needs a small sampling frequency from a single data source, where the other solutions needed a big sampling rate or multiple data sources.

7 Future Work

Having concluded that using logistic regression is a viable solution to minimize the processing stress applied to the WSN module, the next step will be to perfect this system in order to obtain 100% precision on fall detection. In parallel, we will also start testing this system with our own in house developed WSN module. Finished this step, we will start expanding our research to more areas of health care than just fall detection.

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Communication Framework for Emergency Rescue Services Enhanced by Personal Health Monitoring Solutions: Methodological Approach

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Abstract. This work aims to specify and validate a communication framework for healthcare rescue and emergency services enhanced by personal health monitoring solutions. This framework aims at presenting a contribution to the evolution of the actual emergency healthcare services response model toward a national wide communication framework able to enhance emergency services efficiency and effectiveness by the seamlessly integration with personal health monitoring solutions. Following a "participatory action research" methodological approach, this work aims to establish the gap and limitations, verified nowadays, between reactive and proactive emergency frameworks by identifying major risks and misleading needs, leading to the specification and discussion of scenarios where emergency responders benefit from the suggested communicating framework and the value added emerged from it.

This paper focuses on the methodological approach and will describe the most important findings of the first stages: the state of the art, the diagnosis needs and the research model specification.

Keywords: pervasive healthcare, personal health monitoring, emergency services response and communication framework.

1 Introduction

The actual societies are facing growing challenges concerning with healthcare services delivered to their citizens. In on hand, there are financial constraints and budget restrictions inherited by the global financial and economic crisis. In the other hand, citizens have expectations and demands for better and healthcare services. These two forces, considered by some in opposite directions, influence the delivery of healthcare services and shape the design from the next generations.

In the Portuguese society, actual healthcare rescue and emergency services provide and match the expected quality and effectiveness of service. Thought, it is plausible to admit that there is a strong context for changes to happen considering the evolution occurring both on peoples healthcare needs and patterns (e.g. growing life range expectancy, growing number of chronic patient), and on the Information and Communication Technologies (ICT) actual trends (namely in what concerns the empowerment of common citizens with powerful tools for get the knowledge, the new

M.M. Cruz-Cunha et al. (Eds.): CENTERIS 2011, Part III, CCIS 221, pp. 337–346, 2011.

modalities of interaction with other people or specialized professionals and the actual possibilities of monitoring our own health status).

Under this context, we believe that these circumstances can shape interesting opportunities to study and rethink actual rescue and emergency healthcare services policies and scenarios, in order to incorporate citizen's new needs and expectations simultaneously with the enhancing possibilities emerged from the ICT value added.

This paper aims to describe the context, problem, hypotheses and research methodological approach for a research project in its early stage of execution. It also aims to establish the starting point for the research plan, providing the opportunity to discuss and reflect on the project activities and tasks.

This paper starts with an overview over the state of the art related with emergency healthcare services, personal health monitoring and ICT in healthcare services. Based on the context provided by the intersection of these fields, a diagnose about needs and tendencies is presented. Then the article focuses on the methodological approach where it describes the research and action plan in order to persecute the aimed objectives. At the final, a section mapping objectives and the findings expected is presented.

2 State of the Art

2.1 Emergency Healthcare Services

In the Portuguese society, the right of healthcare protection of the population is assured by the country national government, namely by the National Heath Service (*Serviço Nacional de Saúde* - SNS). This service, held by the Ministry of Health reached the 30 (thirty) years old in the year of 2009. The SNS is composed by the following entities:

- Hospitals;
- Local Health Unit;
- Health Center;
- Health Center Groupings.

Since 1981, Portugal also has specific entities responsible for the emergency recue and healthcare services – Integrated Health Emergency System (*Sistema Integrado de Emergência Médica* – SIEM [1]). The SIEM mission is "(...) provide assistance to victims of accident or sudden illness. (...)"[1], and it is composed by the following entities: Public Safety Policie (*Polícia de Segurança Pública* – PSP); National Institute of Health Emergency (*Instituto Nacional de Emergência Médica* - INEM); Firefighters; Portuguese Red Cross (*Cruz Vermelha Portuguesa* - CVP); Hospitals e Health centers.

In a simplified description, the health rescue and emergency procedure is based on the following steps: it starts when someone calls the 112 (European Emergency Number). The call is answered by PSP or GNR (*Guarda Nacional Republicana*). When the rescue call is related with health emergency, the call is redirected to the Urgent Patient Orientation Centers (*Centros de Orientação de Doentes Urgentes* - CODU). Whenever the CODU deploys and emergency team for the emergency calls, they try too find the geographically closer team, from the entities representing the SIEM (INEM, *Firefighters* or CVP).

Regarding the public information promoted by the INEM [1], there are three major attitudes that can and may improve the efficiency of an rescue call related with cardiac arrest, namely:

- Ask for help, immediately triggering the Integrated Emergency Medical;
- Start immediately maneuvers of Basic Life Support;
- Access to defibrillation as early as possible but only when indicated.

Bearing in mind these major attitudes and the new possibilities brought by the personal health monitoring technologies evolution, we believe that there is a wide range of changes and scenarios that could benefit from this strategic alliance.

2.2 Personal Health Monitoring

The scientific and technological developments have boosted the introduction of new techniques and tools in various areas of knowledge. Health has been one of the areas that has most benefited from these developments, perhaps because it aims to preserve the essence and most precious thing a human being - the life.

The necessity and intrinsic motivation for research and experimentation of new techniques and devices to improve healthcare has allowed to achieve a dynamic technological evolution, which is difficult to find parallel.

It is expected that healthcare services focus move from treatment to prevention. However, for this adjustment it is necessary to research and experiment new forms of organization of services and their interaction with citizens. The prospect of new scenarios could include, for example [2]:

- Means of non-invasive diagnosis and treatment;
- Health care at home;
- Short periods of confinement in a hospital environment;
- Rehabilitation processes more efficient;
- Citizens more informed and aware of their health status and treatment.

In healthcare, a technique that is widespread is the use sensors (individual sensors) to collect data for different biomarkers (eg heart rate, changes in electrical potential generated by the heart's electrical activity - ECG, etc.).

Personal Health Monitoring (PHM) solutions have evolved in complexity and features. Despite the diversity of sensors that emerge at a rapid pace, with a view to monitoring of various biomarkers, the concept of PHM has evolved in the direction of sensor networks. These networks arise by the necessity and possibility of monitoring a number of different biomarkers, enabling the preparation of a more complete and accurate picture about the health of a patient.

The introduction of sensor networks is only possible through technological developments in different areas of science, including:

- Miniaturization of devices and equipment;
- Significant increase in processing and analyzing information;
- Materials and smart textiles;
- Wireless communications.

The horizons opened by Personal Health Sensor Networks (PHSNs) [3] allow the design of new scenarios where technological PHM solutions do not refer only to data continuously capture. The increased ability to process and analyze information in real time opens doors to scenarios where PHSNs have the capacity to detect patterns and evidences of potential attacks or anomalies in the health of the individual that is being monitored. Such evidences may be used as alerts to the individual causing it to take measures so as to minimize and, ideally, prevent medical emergencies.

2.3 ICT in Healthcare Services

The current era of Information and Communication provided the ideal context for major changes and developments in key areas for the day-to-day individual and societies. The Public Health has been one of the areas where most substantial progress has been achieved.

However, the different dimensions involved in the health of an individual or society, go beyond the Physical and Mental health, with which we can identify more easily, particularly through recognition of diseases, diagnoses, treatments, etc.

In addition to Mental and Physical dimension, the Social dimension of health has been also the target of evolutionary phenomena providing the emerging of new horizons, possible only by widespread access to ICT by the patients / citizens and health professionals.

Whether through technological advances at the electronics and telecommunications, or through the ability, brought by ICT, of shortening the distance of relationship in a group or network, new channels and strategies start to emerge and try to take advantage of these gains in view of modernization and development of health systems. In Portugal, it is possible to highlight some services that use ICT as a key tool in its strategy, for example:

- Consultation to medical information and / or health;
- Electronic personal health record;
- Book appointments online;
- Personal health monitoring.

The spread of ICT allows providing a set of communication channels to use in a formal and informal way. The use of these communication channels allows the patients / citizens to adopt a more participatory and even more responsible role about his state of health. This can be accomplish through the gathering of information, sharing experiences or participating in thematic groups related to specific aspects of health (e.g. a particular disease, given a clinical episode, etc.).

However, the technological evolution cannot, by its own, guarantee the success of these new strategies or policies.

The latest trend in the context of communication networks in health, focuses on technology-mediated scenarios that allow a direct relationship between the individual and the environment in which it moves, as well as the assets that it incorporates (a form of carrying transparent / non-invasive) in its everyday activity.

The ubiquitous nature and emerging "pervasive" technologies in healthcare, can give some perspectives about future trends of research in the context.

In the specific context of Rescue and Emergency Services, which delimit the field of this thesis project, seems essential to study the potential of assistive and pervasive technology in emergency scenarios.

According to Doukas et al [4] assistive environments represent, par excellence, a framework for PHM devices and enhance the creation of new scenarios and interaction models in which these technologies can be combined with public health services, expanding on the possibility of integrating personal contexts with interpersonal and inter-institutional services.

3 Diagnosis Needs

In this work, we intend to investigate and explore possible developments in the process of communication of information among the victims of a health emergency and emergency medical services that will participate in the rescue operation.

It is intended to reflect on new paradigms of interaction and communication that may introduce capital gains in the process, enhanced by the use of digital platforms, and this may improve the effectiveness and efficiency of the rescue operation with a view to saving more lives, or at least, ensuring a better quality of life as a citizen involved in an emergency related to your health.

Despite the developments that have been seen on the technological characteristics, the expectations of society and its citizens has also evolved. An indicator that shows just that is the average of life expectancy of an individual, born in Portugal, currently located in 79 years [5][6] This number has evolved positively over the last decades: 1990 - 74 years, 2000 - 77 years and in 2007 - 79 years.

The average life expectancy is only one challenge we are facing today. Changing lifestyles, the need for policies and shoved to contain costs in providing health care and the need to improve the quality of health care, represent some of the challenges for which it is expected that technologies and new opportunities communication and interaction can help with clues for the design of possible future scenarios.

Within the scope of research to be conducted around this issue there are several clues that should be considered:

- Integrity Solutions (textiles, sensors, energy and communications);
- Market entry of monitoring solutions for different biomarkers;
- Validation of devices / medical solutions according to the extensive and stringent laws and regulations apply to health technologies;
- Property rights and privacy of information;
- High cost of new solutions and technologies;
- Sustainable business models for new service models to provide health care;
- Social and ethical issues associated with the communication of clinical information.

Finally, and perhaps most important:

- Education and acceptance by citizens of the new models for providing health care for citizens.

This is, indeed, the most relevant element in the entire area. It is not primarily a technological issue, but the reaction and acceptance that consumers / citizens that will demonstrate the new possibilities opened up by technological developments and will determine the future tendecies and policies in health rescue and emergency responde.

4 Methodological Approach

This research project results from the convergence between three main concepts (Healthcare Rescue and Emergency services - HREs; Personal Healthcare Monitoring solutions - PHMs; and Information and Communication Framework - ICF) and is oriented by the following research question: How can the Personal Healthcare Monitoring solutions enhance Healthcare Rescue and Emergency services?

From this question, the main hypothesis is: Personal healthcare monitoring solutions may support and enhance healthcare rescue and emergency services based on an information and communication framework able to combine the specificities from the rescue and emergency environment with the new technological possibilities available.

The proposed research project has well-defined geographic and time boundaries. For the time reference the project use the year 2011 as the actual moment. Meaning as time window of opportunity, the project points to the period from 2011 to 2016, accordingly the National Health Plan 2011-2016 [7]. From the geographic perspective, the proposed project is oriented to the Portuguese reality, mainly because of the specificity of the National Heath Service (Serviço Nacional de Saúde). Nonetheless, for the state of the art and for the measures and new scenarios proposed, the project aims to embed and get inspiration from lessons and conclusions retrieved from other countries that already have done hard work and progress in this field of action.

4.1 Scientific Areas and Context

The scientific context of this work has it main roots in the scientific field of “Communication Sciences and Technologies”. Besides this principal context, there are other auxiliary disciplines that bring value to the project, like: Information Science, by the fundamental role played by the information circulating and resulting from the communication processes; Computation Sciences, by the enlightenment in the state of the art and evolution tendencies on personal healthcare monitoring solutions and devices; Communication in Healthcare, providing de context and specificity where user needs and technology can come together bridging to new horizons.

4.2 Purpose and Goals

This research project has two main purposes: promote the adoption of personal healthcare monitoring solutions in rescue and healthcare emergency scenarios; and propose a good practice roadmap for the implementation of a new communication framework that keeps in perspective the evolution of the actual rescue and healthcare emergency scenarios based on personal healthcare monitoring solutions.

From these two purposes, and considering the research question mentioned above, the main goals, for the proposed research project, are:

a) Understand the actual communication framework in the rescue and healthcare emergency services;
b) Specify a communication framework, in the rescue and healthcare emergency services, enhanced by personal healthcare monitoring solutions;
c) Determine the major advantages and value added introduced by the proposed communication framework;
d) Validate the sustainability of the proposed communication framework for rescue and healthcare emergency services;
e) Design a good practice plan for the communication framework implementation.

4.3 Analysis Model

The presented analysis model has been designed based on Quivy e Campenhoudt [9] and aims to identify and specify the concepts, dimensions, components and measures proposed as organizations structures of the research activities in the project.

The following tables present each one of the three mandatory concepts for the proposed research project.

The first concept specified is Healthcare Rescue and Emergency services.

Table 1. Analysis model - Healthcare Rescue and Emergency services (HREs)

Dimensions	Components	Measures
Healthcare;	- Type of service; - Admission requirements;	- Admission levels; - Availability;
Rescue and Emergency in healthcare;	- Emergency nature: - Reactive, preventive or proactive;	- Admission cost; - Answer time; - Recovery cost; - Actual scenarios; - Actual bottlenecks;
Intelligent emergency management;	- Services - Policies;	- Maturity; - Availability;
Healthcare network;	- Project;	- Citizen know about;

The second concept specified is Personal Healthcare Monitoring solutions (PHMs).

Table 2. Analysis model - Personal Healthcare Monitoring solutions (PHMs)

Dimensions	**Components**	**Measures**
User needs;	- Assisted living environment;	- Maturity;
State of the Art;	-Pervasive healthcare technologies;	- Availability; - Access cost;
Capture and data transmission;	- Electronic and computational perspective;	- Number of users / adopters;
Health data analysis and processing;		
Health data usage;	- Healthcare perspective; - Healthcare impact (physically and mentally);	

The third and last concept specified is Information and Communication Framework (ICF).

Table 3. Analysis model - Information and Communication Framework (ICF)

Dimensions	Components	Measures
Human components;	- Specification; - Validations; - Solved bottlenecks;	- Stakeholders - Actors
Technical components;		- Instruments; - Techniques; - Channels
Workflows, relations and interactions;		- Workflows; - Procedures
Health information data provenience		- Credibility; - Certifications; - Responsibility;
Health information data accuracy	- Prototyping; - Focus Groups;	- Acceptance level; - Viability; - Value added;
Implementation good practices	- Change management; - Risk management; - Actors involvement;	- Phases; - Methodology;

4.4 Research Method

For the accomplishment of the proposed research project, a "participatory action research" methodological approach is suggested. Regarding Rapoport [9], "Action research aims to contribute to the practical concerns of people in an immediate problematic situation and to the goals of social science by joint collaboration within a mutually acceptable ethical framework". The proposed research project requires an empiric approach of the research problem as well a field action plan close to the agents and environment that origin the identified research question. Due to these characteristics, it seems that the "participatory action research" approach is better suited to the nature of the proposed project, instead of other approaches like: historic, comparative, descriptive, relational, experimental or evaluative.

Following the "participatory action research" methodological approach, this work intends to support research activities by:

- Real time and field investigation, by contrast with controlled or laboratory environment;
- Specificity of situations that the project intend to improve, by contrast with abstracting the problem;
- Incorporate changes or evolution to processes and measure consequences in an iterative and flexible context.

For that matter, the presented methodological plan consists in an iterative set of phases that reflect the "participatory action research" approach intended for the research project.

Table 4. Detailed Action Research Model (adapted from [10])

Task	Description
Diagnosing	Identification and problem delimitation
Action Plan	Design action measures and alternatives
Taking action	Implement and experiment action measures;
Evaluating	Studying the consequences of the actions
Learning	Identifying general and major findings

4.5 Research Operation Plan

Table 5. Research Phases: Goals and Tasks

Phase	Objectives	Tasks
1ª Phase	a) Understand the actual communication framework in the rescue and healthcare emergency services;	1. Diagnosis needs
2ª Phase	b) Specify a communication framework, in the rescue and healthcare emergency services, enhanced by personal healthcare monitoring solutions; c) Determine the major advantages and value added introduced by the proposed communication framework; d) Validate the sustainability of the proposed communication framework for rescue and healthcare emergency services;	2. Framework specification (v1); 3. Framework discussion; 4. Framework specification refinement (V2) 5. Framework validation
3ª Phase	e) Design a good practice plan for the communication framework implementation.	6. Implementation roadmap design; 7. Implementation roadmap discussion; 8. Implementation roadmap refinement;

4.6 Data Gathering

The treatment of collected data will be based on the methodological procedures associated with qualitative and quantitative analysis.

Qualitative Analysis: there is the perspective that most data will be gathered from the focus group sessions, as well from reflections and discussions on the topics under research. Due to the subjective and unstructure essence of the data gathered, this work proposes a qualitative analysis to undestand and get conclusions from the data.

Quantitative Analysis: for the procedures based on systematic data collection techniques, as the case of a questionnaire survey, we intend to apply quantitative analysis.

Based on this combination of methods this research project intend to develop a strategy of triangulation of data that allow the enrichment of the research topics and make sustainable inferences.

5 Final Considerations

Underlying the proposals for this research project, there is a set of goals and predictable results we expect to achieve. Firstly, this project aims to promote the adoption of personal healthcare monitoring solutions in rescue and healthcare emergency scenarios and, to achieve this goal, a communication framework for health rescue and emergency scenarios supported by personal health monitoring tecnologies will be proposed. Secondly, we will propose a good practice roadmap for the implementation of the communication framework which aims the adaptation and evolution of the current health rescue and emergency scenarios.

We expect that the methodological approach of the project, described in this paper, proves to be suitable to accomplish these two main goals, in order to create an ajustable scenario to develop the full potentialities of this research.

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The Use of Information Technology in Public Hospitals in the City of Rio de Janeiro

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Abstract. The application of Information Technology (IT) at the medical-hospital services sector, especially in Brazil, reveals yet slow and incipient, due, especially to the particular characteristics from this sector. This article presents results from research aiming at analyzing the application, use and investments in IT in five public hospitals from the municipality of Rio de Janeiro. The field data were collected using a questionnaire applied to the executives directly connected to the management of infrastructure and IT of such hospitals. The analysis of data was by means of descriptive statistics. The research identified weaknesses and problems relative to planning, selection, implementation and use of such management technology and tools at the researched hospitals. It was also possible to identify the hospitals which better use and take better advantage of resources and easiness of this technology so as to facilitate the routine and work processes from their doctors, patients and directors.

Keywords: Information Technology, IT in Hospitals, IT Management, Hospital Management, Health Care Management, Technological Innovation.

1 Introduction

This study presents the main results obtained with the survey performed in five public hospitals in Rio de Janeiro in order to analyze the "IT Management at such hospitals". Among other things, the management structure, the technologies and the use of electronic commerce are characterized.

The research is linked to a national project, conducted by the Laboratory of Practices in IT and Information Systems Management from the Health Sector (GESITI/Health), from the Centro de Tecnologia da Informação Renato Archer - CTI (Campinas/Brazil). CTI it is subordinated to the Ministry of Science and Technology, from which around twenty three institutions take part, each responsible for the execution of research at a Brazilian region.

M.M. Cruz-Cunha et al. (Eds.): CENTERIS 2011, Part III, CCIS 221, pp. 347–360, 2011.

The present work represents the unfolding and improvement of studies performed in 2009 and 2010 which allowed the elaboration of an article published at the proceedings from the VII GESITI Workshop and Connected Event II GESITI/Health – 17/18 of June of 2010 (Campinas – Brazil).

The application of new and sophisticated technologies over the last twenty years in all sectors of the economy is resulting in a degree of organizational complexity with no precedents. This contributes for increasing challenges for organizations when enabling greater capacity of recording, storage, analysis, control and transmission of great volumes of information in real time. ERP is an example of these systems. As says, Lemieux at al., ERP systems are a complex configurable technology which requires important investments to adapt to a specific firm. [1]

On the other hand, the computerized systems are increasingly employed at hospitals aiming at improving the quality of information from the medical area, by means of the computerization of work processes in the field of health as a whole. Frequently, however, the IT application has been slow, partial and gradual as the sector of medical-hospital services has peculiar characteristics at its structure and operational management. Such specificities demand complex models from IT management and, many times, specifics from information flow and decision making process, which encumbers the management as a whole [2]. This way, the introduction of new technological arrangements in hospital environments must consider the manner in which the different users shall deal with tools, as for interpretations, sometimes diverging, determining the effects of technologies in practice and not their technical characteristics. [3, 4, 5, 6, 7]

The necessity for network, processing and storage of data infrastructure in hospitals in order to improve the management of systems in support to the medical research, calls for development and adoption of specialized softwares, founded on diverse technologies [8, 9]. With this, one notices that hospitals are complex organizations, possessing one of the most extensive supply chains involving the most varied sets of processes: organizational (administrative, financial, technological processes, etc.), business (customer support, purchase and sale and marketing issues, etc.), doctors (diagnosis and treatment of illnesses) and hotel (accommodation, food and resting). [10].

The difficult balance budgeting of public and philanthropic hospitals has led many of them to attend insurance companies or by health plans, through agreements properly formulated [11].

On the other hand, the hospital costs are high, due to the nature and characteristics of their supplies which are intensive in technology (due to the necessity of using state of the art technology) and formation of their staff which is intensive in knowledge (requires a varied range of expertise), etc. When dealing with human lives, their management requires attention, dedication and special care, as a simple fault or error may be fatal. Its specificity makes hospital management one of the most expensive, challenging, vulnerable and complex enterprise characterized by low tolerance to faults. Therefore it requires redoubled attention and care at the definition of priorities at investments in technology, as well as their utilization.

Furthermore, the framework was applied in two case studies performed in the health care sector. The reasons for choosing this domain are obvious: currently, the Dutch government demands hospitals to work effectively and efficiently, meaning that they have to be competitive against predefined fares and other hospitals. For this reason, budgets are under pressure and hospitals are seeking for means to reduce costs. This also holds for IM in hospitals. The case studies were conducted at two different hospitals.

However, IT may be used in several ways to facilitate the life of health professionals at the prophylaxis of pre-existing illnesses or their prevention, nowadays with great variety of softwares, applications and equipment aimed at such area, from the control of patient records, through diagnosis up to the most recent application: telemedicine. [12]

IT is one of the critical factors of hospital management and along with Information Systems (IS) are interconnected and interdependent. The IT infrastructure is what offers resources for the development and utilization of IS. The IS refer to the human applications used by the information clients. The IT infrastructure, along the human resources, is composed of several technologies: hardware, software, networks (Internet, Intranet, Extranets, local networks), resources and data management. [13, 14, 15]

To Pouyan et al., "Based on a rich body of literature, professionals (such as healthcare professionals) have some unique and professional characteristics and they are considered different from other non-professionals based on these unique characteristics". [16, p.26]

Medicine professionals (doctors, nurses, radiologists, etc.) and patients expect precise and reliable information from these systems, capable of reducing risks and uncertainties at decision making. Thinking of that, the sector of medicine and health is in search of IT solutions for many of its problems. This is what is taking many hospital directors to invest in IT, as is the case in hospital C, studied at the present research.

Public hospitals have a permanent obligation for service delivery, not only under the usual circumstances, but also in case of a crisis. [17]

To Eze, et al., "whereas other sectors are largely defined by transaction processing, healthcare is defined by continuous monitoring of events and the need for timely response to events through flexible allocation of resources and business processes in a controlled fashion". [18, p.59]

According to the OECD,

> Health care systems today face tremendous challenges – complex care needs and care processes, increased health care demands (especially for chronic conditions), and, fundamentally, an economic landscape where health care systems will have to achieve more for less. Measuring health care quality has a pivotal role to play in meeting these urgent and important challenges. [19, p.11]

In 2009 the US Congress approved the American Recovery and Reinvestment Act (ARRA), which contains special provisions for health care IT. This system will allow every doctor's office and hospital in USA using cutting-edge technology and electronic health records to cut red tape, prevent medical mistakes, and help save billions of dollars each year. The ARRA will provide $37 billion to hospitals and physicians making "meaningful use" of electronic health records, with penalties for those failing to do so by 2015. To improve the performance of health care IT, the act targets $9.4 billion for areas such as telemedicine, data sharing, and broadband technology. [20]

2 Researched Hospitals

As a matter of confidentiality, the researched hospitals were identified as follows: hospitals A, B and D are connected to public universities, C is connected to the Federal Government and E to the Department of Health from the State of Rio de Janeiro. Hospitals B and C are considered as reference at their expertise at their actuation regions. Hospitals A and B attend the population of the city and municipality of Rio de Janeiro, while the remaining, besides city and municipality, also attend the population of the State of Rio de Janeiro. The research subjects are hospital directors, responsible for the management of the hospital and Information Technology infrastructure, with an executive from each one of these areas having participated, at a total of ten directors. Table 1 shows details on the hospitals studied.

Table 1. Hospitals characteristics

Hospital	A	B	C	D	E
Year of establishment	1950	1930	1937	1947	1967
Number of Employees	729	690	830	1.090	437
Number of Beds	600	185	410	540	43
Number of attendances with internment annual	55,000	3,578	35,000	67,000	293
Number of laboratory attendances annual	750,000	136,122	643,000	832,000	486,039

Source: Own elaboration based on Field research.

3 Methodology

At the present study we chose to perform a comparative analysis on the declared use of IT resources among the researched hospitals.

The research, classified as "exploratory and descriptive" was developed in the months of February to May of 2010. The criterion for hospital selection was geographical and concentrated at the Metropolitan Region of the City of Rio de Janeiro - Brazil. The main public hospitals from this region were invited to participate on the research, with five of them agreeing in participating.

The methodology was based on an original and innovative instrument, a questionnaire with over 100 closed and open questions, which has been developing by GESITI project, from CTI. The questionnaire, in turn, has been based on previous and general managements experiences of some programs OECD - Organization for

Economic Co-operation and Development and UNCTAD - United Nations Conference on Trade and Development, as adjusted by the CTI Group GESITI towards Health. Hospitals, by their complexity, diversity and size, have a specific set of challenges and deserve special attention. The goal of the group GESITI / Health from CTI is to develop a characterization and evaluation of information technology management systems in hospitals in various countries.

The questionnaire has been applied to this present research towards hospital TICs management. It comprises six great thematic fields, each one containing the following: a) hospital characterization; b) presence of strategic management at hospitals included at this item: R&D; Innovation and Technology; c) Investments in Technological Innovation and Cooperation for Innovation; d) presence of IT resources, contemplating application programs and specific applications for accounting, HR, stock control asset management, along Telemedicine; e) use of databases (networks, security and telecommunications; network, information security and telecommunication technologies); f) identifying the presence of IT Management, in terms of its solutions.

For the present work, only the more expressive results on the themes researched were considered.

4 Analysis and Discussion of Results

This session describes the analysis and discussion of the experimental results got in the field research and, are presented in the following sequence: Strategic Management, R&D and Technological Innovation, telemedicine, Equipments, Network and Information Security Technologies, IT Management and Database and E-commerce.

4.1 On Strategic Management

Only two of the researched hospitals (A and C) execute Strategic Planning (SP) in a systematic manner. At the remaining hospitals there is no SP systematization and the strategies are developed based on their direction's intuition and at an informal manner. The strategic orientations, arising from such, are gathered in fairs, congresses and seminars where they take part. There is also no determined periodicity for SP review, generating the perception that the sectorial plans are developed sporadically.

By comparison of SP practices from hospitals A and C it is possible to notice some significant differences and similarities, presented as follows.

In both cases the periodicity of SP review is from six months to a year. At A, SP involves high and middle management, and SP deployment in Action Plans and Strategic Projects ends up being of partial knowledge to employees at the operational level. In such case, are few, inclusive, the employees which state being aware of the SP existence. On the other hand, at hospital C, outstandingly the best structured and computerized of the five hospitals researched, employees of all hierarchical levels participate and take part on SP.

The sources from which the business strategies are created are less rich at hospital A (the analysis of present and potential demand with high degree of client importance and average degree of resource importance – capacitation, motivation, availability, etc.) than that of C, which considers these other sources (scenario analysis, competition – threats and opportunities, degree of customer satisfaction, benchmarking execution, mission and recognized competencies).

For the follow-up and reformulation of strategies, hospital A uses PDCA as instrument for evaluation and control, while C uses their own integrated system, being such, possibly, the greatest difference between them, considering SP.

4.2 R&D and Technological Innovation

The activities of Research and Development (R&D), in the period of 2006 to 2010, have differing importance amongst hospitals studied. In this case, four of these hospitals (A, B, D and E) attribute average importance to such activities, while hospital C assumes a distinguished position giving high importance to R&D activities.

As for the acquisition of external knowledge, hospitals C and D are leading, where this activity is considered of high importance. For the remaining hospitals (A, B and E) this is an average importance activity. However, in regards to periodicity, in four hospitals this activity is executed in a continuous manner, and only at hospital A it occurs occasionally.

For management from all hospitals studied the intensive use of IT would improve their competitive performance, speed up the dissemination of information and aggregate value to the services rendered by them. Nevertheless, researchers were unanimous in acknowledging the existence of financial difficulties for investment in IT, although in only one case (hospital B) the type of difficulty was indicated, being such related to budgetary allocation. At the majority of hospitals researched (four of them) management considers the qualification of its staff as being sufficient for undertaking IT implementation, except as to that referring to technological innovation, e-commerce and Telemedicine. This, in a way, makes a contradiction evident when observing the low efficiency of such hospitals at the use of IT.

Also only at two hospitals (C and E) the existence of external environment monitoring mechanisms was reported, in regards to new technologies, customer interests and strategies from the competition. Such result, however, was expected due to the formal existence of Strategic Planning at hospital C. What is surprising, however, is that hospital E does not have SP formally instituted, although it affirms being able to monitor the external environment.

Considering investments already made in technological innovation over the last three years, there is no great difference between hospitals, in percentage terms, with two coincidences between them: a) hospitals A and D invested between 2% to 3% of their earning at such period; b) hospitals B and C invested more than 4% each. Hospital E invested between 1% and 2 %.

In regards to areas of investment in technological innovation, the hospitals indicated differing priorities, with little coincidence between their options. Hospital A foresees investing only in integrated management systems of ERP type. Hospital B foresees investing in their operations. Hospital E wishes to invest at management and stock control (warehouse system). On the other hand, hospitals C and D are more ambitious and intend on investing in other areas. As for hospital C, it has foreseen investment at hospital management, operations, distance education (DE) and in a specific system, known as Picture Architecture System. Hospital D foresees investing at the following areas: management, operations, warehouse system, ERP, DE and telemedicine.

With hindrances to technological innovation, hospitals A, B and D indicate the existence of low staff qualification, being that B and D allege also deficiency in allocation. For hospitals C and E the biggest problem derives from bureaucracy.

Concerning the use of a quality system, or certification at international norm standard, in this case ISO 9000, 14000 or another similar system, only hospital C reports it. This, in a way, shows the weakness of the majority of these hospitals (80%) in defining and monitoring the conformity of their products and services.

On the other hand, it is interesting to observe that, even in the case of hospital C, which possesses an implemented and accredited quality system, there is no report of existence of quality tools such as KANBAN, 5S, Ideas and Suggestions Program, etc. This makes an apparent contradiction evident.

The importance of the introduction of new technologies between 2006 and 2010 was considered high for hospitals A, B, C and E, and average for D. During this period, the five hospitals were involved in cooperative arrangements with other organizations so as to develop innovative activities.

Table 2. Factors which jeopardize Technological Innovation Activities

Hospital	A	B	C	D	E
Lack of qualified staff	High	High	High	High	High
Difficulty for adaptation to standards, norms and regulations	Low	High	Low	Not relevant	Low
Shortage of appropriate financing sources	Averag e	High	Low	High	Low
Lack of information o markets	Low	Not relevant	Not relevant	Not relevant	Not relevant
Shortage of adequate external technical services	Averag e	Not relevant	Not relevant	Not relevant	Not relevant
High costs of innovation	Averag e	High	Low	High	Low
Lack of information on technology	Low	Average	Low	Average	Low
Weak consumer response as for new products	Low	Not relevant	Average	Not relevant	Average
Organizational rigidity	Low	Average	Average	High	Average
Scarce possibilities of cooperation with other companies/institutions	Not relevan t	Low	Low	High	Low
Centralization of innovative activity in another hospital	Low	Not relevant	Not relevant	Average	Not relevant

Source: Own elaboration based on Field research.

With regards to the factors which jeopardize innovation activities at hospitals the shortage of qualified staff is the gravest of all and affects the five hospitals researched to the same extent.

On the other hand, the "lack of information on markets", the "scarcity of adequate external technical services" and the "centralization of innovative activity in another hospital" are the factors which lesser jeopardize hospitals in a general manner, with practically the same degree of importance in all of them. Table 2 well illustrates these factors.

4.3 Telemedicine

Of the hospitals researched only D practices Telemedicine. The activities from this area are performed at the hospital's head office and involve the following expertise: cardiology, intensive medicine, neurology, radiology, pathology, video-endoscopy and gynecology, where researches are performed. Besides these, telemedicine is also used in emergency medicine, dermatology and oncology.

The most common use of this technology is at diagnosis and following-up these expertise, being the majority of knowledge of such practices derived from colleagues, formal training program in telemedicine and medical or post-graduation training.

The peripheral equipments used in videoconferences are: radiological scanner, ultra-sound device and tocogynecological monitor. The telemedicine set used at the hospital involves the expertise of oncology and gynecology and the assembly is composed of interactive-video, storage and image issuance and text transmission, with the sharing of images at the computer screen using audio.

4.4 Equipments, Network and Information Security Technologies

The five hospitals use the following technologies: LAN, Routers and Switches. Three of them use remote access/Wi-Fi: hospitals A, B and D. Three also use VPN: A, C and E.

In regards to the quantity of personal computers (PC) they possess there is a great variation between hospitals, from 50 (hospital D) to 2,300 (hospital C). Hospital A possesses 500 PCs, B 260 and E 157.

The variation also occurs as to the number of PCs connected to the local network. It is verified that only hospital C possesses the totality of its PCs connected to the local network (LAN). Hospital E has 80%, A 70%, while B and D each has only 40%. Considering that this is an indicator of the integration between Systems, People and Processes, but not the only one, we can conclude that only at hospital C it is possible to have full integration between such elements. Figure 1 shows these percentages.

The variation also occurs as to the number of PCs connected to the local network. It is verified that only hospital C possesses the totality of its PCs connected to the local network. Hospital E has 80%, A 70%, while B and D each has only 40%. Considering that this is an indicator of the integration between Systems, People and Processes, but not the only one, we can conclude that only at hospital C it is possible to have full integration between such elements.

In regards to the PCs connected to the Internet there is also a great variation between hospitals. As shown by Figure 2, hospitals A, C and D have all your PCs connected to the Internet. The hospital E has 80%, and hospital A has only 40% connected to the Internet.

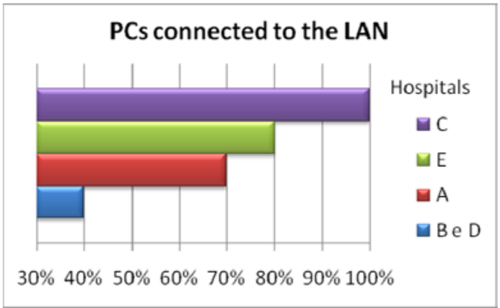

Fig. 1. Percentage of PCs connected to the LAN
Source: Own elaboration based on field research

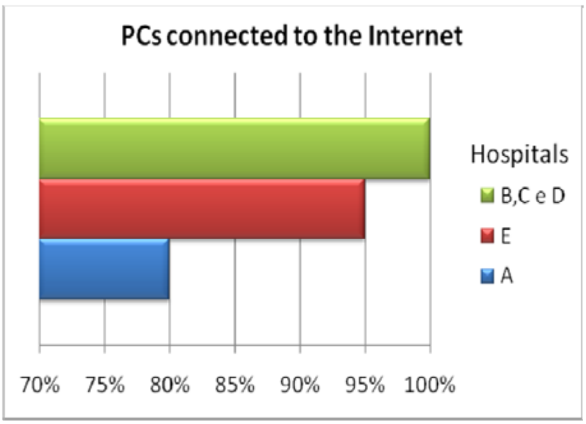

Fig. 2. Percentage of PCs connected to the Interne
Source: Own elaboration based on field research

As for the use of network management Systems, there are only two hospitals using them: A and C. Thus, these hospitals stand out in the use of network technologies, where from the ten listed technologies for research, nine are used. The technology not used refers to advanced network services.

However, the five hospitals have the same investment forecast in Network Technologies, which is from 6 to 12 months.

Regarding information security all hospitals use Antivirus Software and single Login.

As for the access identity management only hospitals A and D are users.

Intrusion Detection System (IDS) also has only two users: hospitals A and C.

And lastly, Firewall system, only two hospitals do not use it: B and E.

Conclusion: from the seven researched technologies on information security, hospital A is ahead with the use of six, C is in second place with the use of five technologies and D in third with 4. Hospitals B and E are tied with the use of only two technologies.

As Information Security is one of the most critical factors in IT, the investment in this area becomes strategic. However, according to that shown on chart 2, it is correct to observe the following:

a) hospitals A and B only intend on investing in security after 12 months. For A, this may be justified, as this hospital demonstrates being well in such aspect using six of seven security technologies. But in B's case, using only two of these technologies, this fact is preoccupying, making evident that for this hospital information security is not strategic;
b) hospitals C and D have forecast of 6 to 12 months in order to invest in security. For C this may be justifiable, once this hospital possesses five of these technologies. However, for D, using little more than half of them, investment forecast should have greater term;
c) as for E investment forecast seems to be coherent with the standing for the hospital which, counting with only two security technologies, considers strategic the decision of investment in the period of 3 to 6 months.

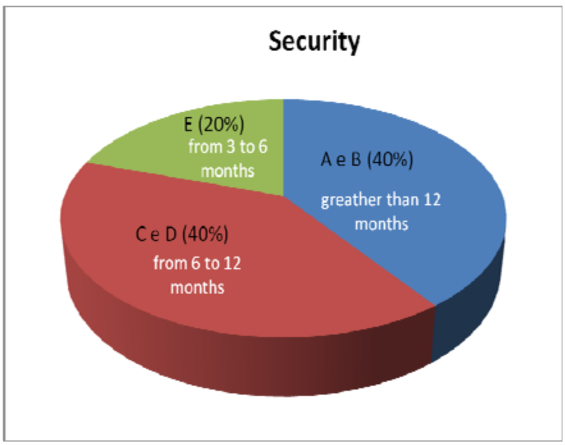

Fig. 3. Estimate of investment in information security technologies
Source: Own elaboration based on field research

4.5 IT Management and Database

As for the use of more sophisticated management systems hospitals, in general, do not do well. Only hospital A and C stand out. From the ten technologies composing this item, hospital C is better equipped, detaining eight technologies (Enterprise Resource Planning – ERP, Collaboration, Decision Support Systems, Business Intelligence, Data Mining, Financial Software, HR Software and Patrimonial Management Software) not using only the Applications Integration System and the Balanced Scorecard.

Hospital A comes in second with the use of six technologies (ERP, Decision Support Systems, Financial Software, HR Software, Patrimonial Management Software and Applications Integration System).

Hospitals D and E occupy third place. The first uses Financial Software and HR Software, and the second uses ERP and Financial Software.

Hospital B occupies last place with the sole use of Financial Software.

The investment forecast in IT Management solutions is the same at hospitals A, C and E, that is 6 to 12 months. At hospital B forecast is more than 12 months, and at D 3 to 6 months.

All utilize Database Management software which varies between simpler software, MySQL, and a more sophisticated one, ORACLE. Hospitals A and B use SYBASE, C ORACLE, D and E MySQL.

Practically the same departments from the researched hospitals utilize Database at their activities, being them: Administrative, Financial, Hotel, Urgency and Emergency Room, and Stock Control. The database servers from these hospitals use the same type of operational system, Windows.

The investment forecast for storage devices is the same in all five hospitals and is between 6 to 12 months.

4.6 E-Commerce

All hospitals use the Internet since 2001, or previously, for the following purposes: search for information, communication with public authorities, banks and financial services.

In order to monitor the market (following prices) only hospital C does not use the Internet, as well as does not plan on using it, at least for now. The others make use of this service since 2001, or previously.

Regarding information on Internet sites, receipt of digital products, freedom in distance education (DE) all hospitals make use since 2001, or previously.

Referring to website only E does not have it, although it has plans for development over the next 5 years for activities related to the sale of goods and services.

As for the use of the Internet for activities for marketing hospital products, the only one to do so is hospital C and it operates as such since 2001, or previously. Hospitals B, D and E plan on using it over the next 5 years and only A is not thinking on using such resource over the next few years. For activities of survey/contact, client customized page (with personalized product presentation), integration with backend systems and provision of post-sales support, two of the five hospitals utilize the Internet: A (since 2008) and C (since 2001, or previously). All others plan on using over the next 5 years.

5 Conclusion

Overall, at the researched hospitals, IT alignment to strategic objectives and organizational business needs seems to be little used. Thus, the first conclusion that can be taken from the study is that, generally, three hospitals (B, D and E) are at the same level as to the use of the studied technologies, with no noticeable differences between them. A little ahead is hospital A. In this case it is possible that the execution of strategic planning in which the high and middle management participate, and the unfolding into Action Plans and Strategic Projects have good contribution at the development of this hospital. However, hospital C stands out in the use of technologies, which guide the elaboration and execution of the strategic planning, staff qualification and infrastructure.

Nevertheless, it is important to remember that these last two are the only hospitals to execute Strategic Planning in a systematized manner and that, only in C's case, such planning involves employees from all hierarchical levels, is well unfolded into Action Projects and Plans and is fully integrated to the hospital management model. However, in all five hospitals one notices that there is still much to be done, especially in regards to the information technology that, if well managed, could contribute for the improvement of administrative and operational development at such hospitals. Referring to telemedicine, there is still a great gap to be filled, even at the only hospital using it, given the high potentiality of such technology, especially in therapies.

The study suggests also improving the performance of hospitals as for the absence of a Quality Management System (QMS) formally instituted, as ISO-9000 norms, except at hospital C, the only one to possess accreditation. On the other hand, it is interesting to observe that, even this hospital possessing implemented QMS, there is no report of use of total quality tools such as KANBAN, 5S, Ideas and Suggestions Program, Six Sigma, etc. This makes clear an apparent contradiction for an accredited hospital. These observations, in a way, show the debility of the majority of such hospitals (80%), if not from all of them, in defining and monitoring conformity of their products and services.

Another issue pointed by the research refers to the level of staff qualification when dealing with technological tools. At the majority of hospitals investigated (80%), staff is considered sufficient for executing the implementation of IT; however, from the technological innovation point of view, the same staff is perceived as low qualified.

Ultimately, besides the aspects noted at the present conclusion, there are numerous preliminary data suggesting greater deepening of the present project aiming at the execution of new comparative researches and analysis with other hospital units from the region, in the perspective of visualizing the "state of the art" in the process of IT management in hospitals from the State of Rio de Janeiro.

6 Future Researches

The Project GESITI / Health from the CTI (Center for Information Technology Renato Archer), Campinas/Brazil, in close cooperation with Post-Graduate Program in Management and Business Strategy of Federal Rural University of Rio de Janeiro / Brazil (Programa de Pós-Graduação em Gestão e Estratégia em Negócios / PPGEN da Universidade Federal do Rio de Janeiro/Brasil), are planning to conduct further research, aiming to expand the study for at least 30% of the other state hospitals in Rio de Janeiro, right until the year 2015.

Hopefully, with this initiative, a deeper understanding of the main problems of these hospitals and thus increase the subsidies aiming at the improvement of hospital management in this state.

Within this scope, the GESITI project as a whole, has the goal to make a strategical planning as well a comparative study with similar results between all Brazilian hospitals as well others countries. It is hopped this will have a large impact on the management issues in hospitals, aiming, at least, the improvement in saving lives.

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Information Management, Proposal for an Integration Platform Using Metadata

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Abstract. The world population is aging and human resources are beginning to become too scarce to maintain adequate care for an increasingly elderly population. The elderly population requires continued care, and their relatives cannot answer that need. To ensure that elderly populations have continuous care, various systems for assistance and monitoring are being researched and deployed. However there isn't a platform that can integrate all the existing systems. This article intends to present an initial study performed and the resulting architecture of a complete system integration platform for applications that cover various areas of biopsychosocial well-being. It has as its aim to store collected data from different systems using metadata, making a patient medical history that can be consulted by qualified personnel.

Keywords: Gerontechnology, System Interoperability, Elderly, Metadata.

1 Introduction

We are facing an increasingly aging population [1, 2]. Due to manifesting a propensity for poorer health with advancing age, the elderly population needs increasing care. Another aspect of today's society, is the lack of time, by the active members of the family to take care of their elements. These two factors are reflected in the fact that, fewer families have the opportunity to provide the necessary care for their elders [3]. This care translates into assistance for the simple activity of daily living, monitoring of physical problems that elderly people present and the necessary coexistence for humans as social beings [4]. Furthermore, it has been verified that the increasing age of the workforce, is making the elderly population continue being active members of society [5]. However, the elderly are more prone to disease and falls, making them more physically vulnerable, though requiring increased monitoring [6].

Due to these factors, there is a need for systems that improve life quality for elders. One of these systems is the Elder Care [7]. The Elder Care project, covers various aspects of the biopsychosocial well-being of the elderly, by extending the radius of action for social and emotional development. To cover the various areas of biopsychosocial well-being, three modules will be developed: Local Monitoring, Virtual Common Room and Control Center. Due to using a modular architecture, new modules may be added in the future, and bring new features to the Elder Care project.

M.M. Cruz-Cunha et al. (Eds.): CENTERIS 2011, Part III, CCIS 221, pp. 361–370, 2011.

The Local Monitoring consists of three sub-modules: the Body Monitor [8], the Personnel Locator and the Easy Interface Commander. The Body Monitor collects data from sensors, detects falls, and is used to monitor the elderly. The Personnel Locator verifies if an elderly is lost, suggesting him a path to a nearby known location. The Interface Commander is a visual interface with which the elderly can interact with the Elder Care System.

The Virtual Common Room consists of two sub-modules: Communication Center and the Voice Commander. The Communication Center enables elderly to communicate with other people by video conference, telephone call or instant messaging. The Voice Commander allows the elderly to interact with the application by voice commands.

The Control Center consists in three sub-modules: the Information Management (IM), the Alert Management (AM) and the Contact Management (CM). The Information Management manages all the information from the various modules coupled to it. The Alert Management manages all alerts and events from the various modules. The Contact Management manages the contact list of the elderly. The interaction between the modules of the Elder Care project is shown the Fig. 1. The work presented in this article is focused in the sub module IM.

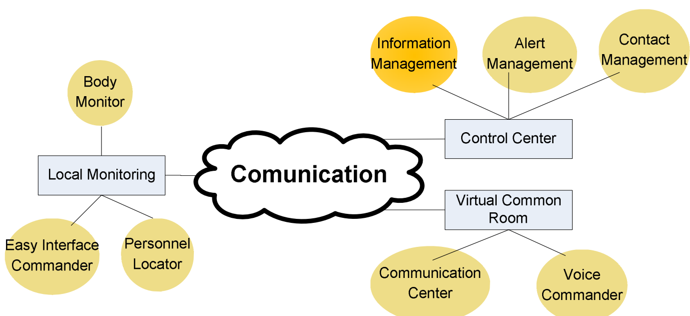

Fig. 1. Elder care project modules and sub-modules interaction

The concepts that will be used, as also, as its meaning in the scope of this project are: a User is a person, elderly or institution that can access to the functionality of the system. A Sensor node is an agent of, and for the system. It is connected to a user entity. The Sensor node provides the information registered by the sensors connected to him. A Sensor is a piece of hardware that collects data and is linked to an elderly or institution. Integration is the linking that is made to connect different systems, to obtain more accurate results. A middleware is a system that enables the exchanges of information between different systems or platforms. The Information Management (IM) is the information repository and the integrator platform for application that cover various areas of biopsychosocial well being.

In this section it is identified a problem that affects the elderly population, and how the Elder Care project aims to find some paths of improvement. It was also described how the project is designed and it was also described the various components of the Elder Care project.

This article is organized in five sections. Section two (background) presents the concepts of systems interoperability, metadata and gerontechnology. Section three (challenges) introduces which motivation and targets led us to develop this project. In section four (information management architecture) discusses the choices made to develop this work. In section five (conclusion and future work) are presented the advantages that the development of this work will bring and are explained the features that will be performed in order to maintain, the scalability of this work.

2 Background

After the contextualization of the topic of this work, it will be presented the concept of systems interoperability and how it solves some communication problems. It is also essential to understand, the evolution that took place over time, in the improvement of the life quality of the elderly. To show these improvements, a chronology of significant milestones in the gerontechnology area is shown.

2.1 Systems Interoperability

In this section, it will be presented the concept of systems interoperability and the conditions that led to its development. It is also shown, how some technologies are used to solve the interoperability problems.

The systems interoperability allows users to perform tasks, regardless of hardware, operating system or applications, interconnected by different data networks [9].

The tendency of the 70's and 80's, was the creation of centralized applications, without taking into account, the need of cooperation between systems. This led to large systems, created by various subsystems and supported by distributed architectures [10]. This concept evolved into cooperative systems, creating the need of interaction between deferent's systems. One solution to solve the communication problems is to follow patterns. In a simple way, a pattern is a document with a proven solution to solve a common problem. However, the notion of patterns is already used in a natural way as a proven solution, to solve problems of the daily living [11].

However, for interoperability, there is the need of communication between machines, which is possible through the use of data networks. Data networks are groups of computers, interconnected by communication channels that allow interaction and resources sharing among users [12]. But there are some different types of networks, so it was necessary to create a model, which would allows communication between all different types of networks. The conceptual models Open System Interconnection (OSI), has brought great advantages in standardization of networks and was the basis for future implementations. One of those implementations was the Transmission Control Protocol/Internet Protocol (TCP/IP).

Knowing how information flows between machines and how the different network interact, it is important to know what technologies allow the execution of remote functions, thus allowing the development of distributed applications. Some of these technologies are: Remote Procedure Call (RPC), Java RMI and Distributed Component Object Model (DCOM). Each of this implementation is linked to a fixed technology, restricting the scalability of applications which use them. In order to allow technological independence, Web-Services were created. The World Wide Web Consortium (W3C) defines Web-Services as: "A Web service is a software system designed to support interoperable machine-to-machine interaction over a network. It has an interface described in a machine-processable format (specifically WSDL). Other systems interact with the Web service in a manner prescribed by its description using SOAP-messages, typically conveyed using HTTP with an XML serialization in conjunction with other Web-related standards." [13]

In order to make well designed applications, it is essential to plan and organize the ideas for a project. The Service-Oriented Architecture (SOA) enables this structuring of ideas. SOA is a flexible set of design principles, used when developing a system that aims to create a set of loosely-coupled services (as independent as possible).

All of these technologies are used to design, application and work with data, however it is essential to know its structure and how it is possible to organize the data. This information can be accessed using metadata. With the use of metadata it is possible to access to the structure and organization of data; enabling different systems to exchange data, organized in the correct way.

In the Elder Care Context, the data will come from different sources and stored in a remotely accessible database. It will also be possible to create and change data structure, previously created using metadata.

2.2 Gerontechnology

In this section will be presented the concept of gerontechnology, showing how it has been used to improve the life quality of the elderly.

Table 1. Some important systems of monitoring

Year	Type of monitoring made
1988	Physical monitoring, sleep hours, hygiene habits, weight and use of the computer. The data were stored without generating alerts or without make any analysis of data in real time [16].
1995	Collecting data to monitor the conduct and evolution of health problems in elderly, detecting changes in health status. Data analyses are done off-line, and generate reports for those participants who had significant changes [17].
2000	Using non-intrusive sensors to detect activity of daily living of elderly. This system does not have any real time action with the collected data, which are stored and later analyzed [19]. However, the patent covers a system that responds to the collected data in real time [20].
2008	Six European countries (Portugal, Spain, Italy, Germany, UK and Ireland) have contributed to the development of the project Complete Ambient Assisted Living Experiment (CAALYX) [21]. This project is to monitor the vital signs of the elderly, detecting falls and location of the elderly, being this at home or outside it. It uses existing medical sensors. When the system detects an anomaly, it compares it with the existing historical, thus detecting changes in the health condition of the elderly, minimizing false alarms. While the elder is at home is used an integrated system (computer / television) with Internet access. To complete the system its used mobile phone nokia (N95) to detect the location of the elderly when is not at home [21]

Gerontology is the scientific study of the aging process that was introduced by Elie Metchnikoff in 1903. It studies the physiological and psychological aging process of all living beings, not only man [14]. The gerontechnology brings together two disciplines, gerontology and technology, resulting in a concept that describes the study of the aging process which resorts to the use of new technologies.

There are three main ideas that involve gerontechnology. The first is being able to include the elderly in the technology progress; the second is that the age or sex cannot be an impediment to the tasks completion; the third is that the elder must have full control on the technology that surrounds it [15].

Over the years, several advances have been made to improve the life quality for elderly, to illustrate that it's presented the following table 1, organized chronologically.

3 Challenges

The challenge behind this work is: How to connect several modules, which together aim to improve the life quality of elderly, exchanging information quickly, securely and efficiently?

Due to the increasing number and type of monitoring sensors and the existing trend towards the development of new types of sensors, there is also an increase in the numbers of monitoring applications. For this reason it is necessary to create an effective middleware that serves as bridge between all these different applications.

The architecture presented in this paper, must respond to the following issues: how to be an information repository, of all the data produced, by the systems connected to the platform? How to make an elderly history, that can show the normal condition and habits of the elderly? How this architecture will integrate different platforms? How can be this architecture scalable?

4 Information Management Architecture

In this section, it will be presented some possibilities to implement the architecture for this middleware, as also the technologies that will be used, in is development.

At this moment, this proposal it is not focused on any aspect of the security. This will be considered in a later stage of the work.

For the messages that will be used to communicate between systems, some methods were weighted: Health Level Seven (HL7), develop a new protocol and Extensible Markup Language (XML) messages. The HL7 messages are a viable solution, although the implementation of these messages, will bring a great complexity to the architecture, and this middleware isn't only a medical system. The new protocol will not be developed, because it was found a more feasible and nonspecific solution. At last the XML messages, will be adopted because it is possible to make a validation with a XML Schema Definition (XSD) file, it follows the rules of an open standard and it is understandable by humans and machines.

Knowing the technology used for the messages exchanges, it is essential to define, what technology will be used to communicate between systems. Two ways of communication where weighed, one based in sockets and the other based in web-services. Receiving messages directly by socket will be used only to transmit short messages, and with a high level of priority. The Web-services, will be used for communication between different systems, because they are independent of the technology, they use the WSDL as specification and as the advantages to use the XML natively. In the event of the existence of a high number of requests and the web-services can't assure the answer, the communication for urgent messages, will be assured by a proper protocol, whit the use of sockets.

The research team behind Information Management, has decided to implement a scalable architecture, this enables that any kind of system that covers any areas of biopsychosocial well-being, can be connected to this middleware. The proposed architecture consists in a set of services that can: create a data structure, require storing the data sought, by the external system connected to the IM, interlinking the various external systems connected to the IM and get to understand and use information that is stored in the IM.

To store the information from different external systems, is necessary to prepare a structure that contains the data, however each external system has different needs. The solution is to create one structure for each external system, using metadata. With this solution, it is allowed, to each system, define the data structure that it needs, to store its data. Using metadata, enables each system to set the desired structure and proceed for their establishment in the IM. To be able to create the structures for the various systems, the metadata will contain information about the tables to create, their names, their fields, the definition of the fields and the connections between tables. This information is enough to prepare a data structure and enable the IM to receive data. All the information that an external system sends to the IM, is stored in the correspondent structure, being added a time stamp, and the user who made that record.

The external system may needs to change the previously created structure. Depending on the necessary changes, there is a planned response. If it is necessary to add more fields or tables in the structure, the metadata are update and the physical structure in the IM is change. The changes that are made in the structure and in the metadata are recorded. If it is necessary to make changes that require the elimination of data, there are two possibilities projected: the first is to mark data and structure as deleted and create a new structure. The second is the elimination of the structure and all the data contained in it, and create a new structure. The first option is recommended because, although the data and the structure are marked as deleted, it can be restored. It also keeps the historical data that the external system has stored. The second eliminates the data and structure definitely, getting these inaccessible. After delete or mark as delete, the new data structure can be created.

Being the IM a platform that integrates external systems, it needs to know and make known the services that are provided by the external systems connected to the IM, thus enabling to interconnect various systems. When a service, that is provide by an external system, is updated, is necessary to notify all the systems that are using that resource, advising them that an feature update have occurred. In order to solve this problem were discussed three possible solutions: the first one is, "compel" the external systems to provide a fixed service to allow access to IM, enabling the IM to provide a list of all available services, keeping this list updated. The IM have to be notify when an update occurs. The second one is, make part of the registration process of external systems to fill out a list of available services, and how to access them, keeping this list updated. It is necessary to notify the IM when the list is amended. The third one is, create an ontology which allows sharing and questioning any knowledge in the IM domain.

The option to ensure, that the external system has a fixed form to list the services that it provides, was not adopted because, it can't be ensured that the external system has the list updated. It is also not adopted because it forces the external system to provide a service only to connect to the IM. The option to make part of the registration process, from the external systems, to fill out a list of available services provided, was not adopted because it would not be a guarantee, that the list would remain updated, and still, has the disadvantage of building services and data structures, in the IM only to list the available services. The option to create ontology was adopted, because it provides to external systems the knowledge of how to interact with the other systems, and what kind of services are available. With ontology it is possible to define a set of objects that belong to the IM domain and the relationships between these objects, thus allow making inferences, about the objects in the domain of the IM. In a simplified way, that allows external systems to question the ontology about, how to interact with the services provided by the IM, which services are available and what is the meaning of the existing content within the IM. In the Fig. 2 is an example of an external system interaction, retrieving information of the ontology about how to use the services provided by the IM.

Using ontology, it is also possible to extract knowledge that is stored in the IM. With an ontology, it is possible for external systems, not only use IM as a data repository and a way to interact with other systems, as it is also possible to know the data structure used by other systems and what knowledge is in the structure.

The ontology will separate the business logic, from the data logic, thereby allow have access to a list of services, separated from the knowledge instilled in the data, stored in the IM.

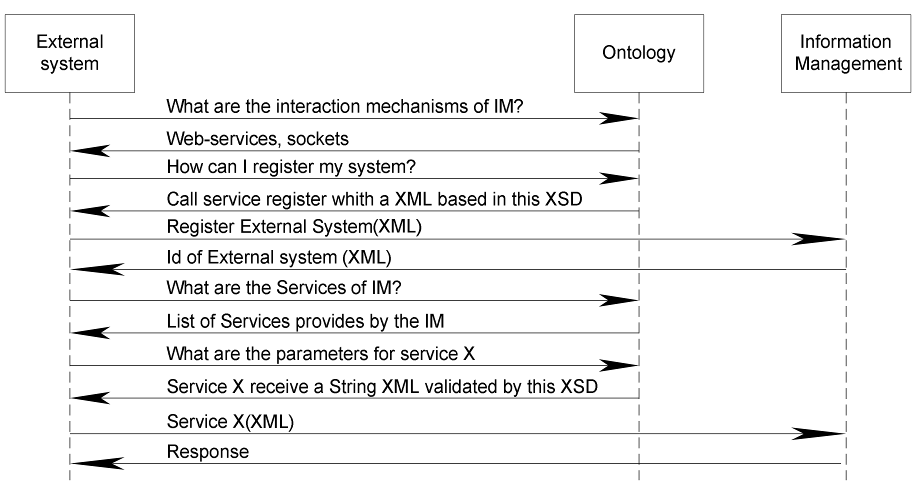

Fig. 2. Example of external system questioning the ontology to use the services provided by the IM

Up to this point, it was explained, how this architecture was projected to collect, store and share knowledge. It is essential to know what mechanisms, allow the extraction of information. To extract information, it is necessary to know, how it is organized and what information is sought. To facilitate this process, it can be returned the existed data structure, that a particular IM system has created. In that data structure, that is returned, is possible to obtain information on, how many tables were created in the structure, which are the names of tables, the fields of the tables, and the data type of the fields. In short it is returned the data structure, that was created by the external system and the knowledge that it contains.

In the IM, there is a pre-defined the structure, to store data from sensor systems. The sensor systems are seen as a set of sensory nodes, where each node is a unique element of the sensor system, which is connected to an elder. The sensor node is an aggregator of sensors, which can record data, from various sensors, in real time. When a new sensor is registered, the name of the table to be created has to be set, that will store data from the sensor, identify the sensor and the field's names of the tables to create. With this information, it is possible to create the structure for a sensor and return an identification key, for the sensor. This key is used to identify the records entered by the sensor. It is also possible that several sensors of the same sensor node, store data in the same table. To identify which stored data belong to which sensor, it is added the identification key of the sensor in each line of the table, which the sensor saves. When a sensor is registered and it stores data in an existent table, it is not created a new table for this sensor.

The sensor node may need to store other data than those from the sensors, in this situation the sensor node can create a similar data structure like those of the external systems.

5 Conclusions and Future Work

Besides having as its primary objective, the improvement of life quality, for the elderly, it also intends to supply, a base platform that interconnects different modules and projects. In this way, it will be made available a platform, which has as its goal, the gathering, storage e supplying/lookup of data. This project will remove the concern for the storage of data and for the connection of several projects, thus allowing whoever uses this platform to specialize in certain tasks.

This project will be an asset to existing software, because it doesn't have as its goal to work as a single independent project. With the use of ontology is possible to know the possible interactions between different systems and the knowledge that is stored in the IM. This project has also the purpose of supplying data exchange mechanisms. This functionality will allow the exchange of data between projects, thus allowing a more thorough evaluation of the elderly well-being.

This project seeks to give its contribution to the problem of systems interoperability by allowing different projects with similar purposes to help solve problems for the elderly population. With the implementation of an ontology it is not necessary to know the structure or the working model of these projects. This information is guaranteed by the ontology, because it can provide the possible interactions between objects of the IM and the external systems. The system comes with a set of interactions predefined in the ontology, with which it can learn to create new interactions in the future. This guarantees the independence of the projects and external modules, only the data being collected is important and not how it's collected.

With this architecture the model of operation from database engines is changed, because they are optimized to work by records in tables, but in this architecture the need is to have a table by sensor, which will lead to the creation of multiple tables with identical records. With this data organization, the information stored by the sensor is accessed without perform complex queries on the database.

The next step to be performed is to begin the implementation of this architecture. It will be defined a communication protocol and the XML structure of the messages to be exchanged. This architecture has to enable communication between systems, with a set of simple rules. With that it is expected to show the existence of a weakness in the systems integration with a similar objectives but distinct purposes.

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A Mobile Health Care Rule-Based System

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Abstract. The relation between patient and physician in most modern Health Care Systems is sparse, limited in time and very inflexible. On the other hand, and in contradiction with several recent studies, most physicians do not rely their patient diagnostics evaluations on intertwined psychological and social nature factors. Facing these problems and trying to improve the patient/physician relation we present a mobile health care solution to improve the interaction between the physician and his patients. The solution serves not only as a privileged mean of communication between physicians and patients but also as an evolutionary intelligent platform delivering a mobile rule based system.

1 Introduction

When faced with the problem of non critical patient monitoring, most modern health care systems, either private or public, rely on a series of meetings between physicians and patients.

These meetings tend to be succinct and rather sparse in time, specially when taking place on an overloaded and inefficient health system scenario, like the ones observed in many countries. Due to the numerous limitations imposed on the quantity, quality and time availability for each of these meetings, often the physician can only get a partial and distorted medical perception about the actual condition of the patient under observation [3]. Such poor quality information can lead to medical misjudgements, late diagnostics and even induce medical decisions with critical repercussions in patients' lives.

Actually, it is often the patients that do not cooperate with the health care system in order to attend more medical meetings and to spend more time in each of those meetings. Again, the reasons for such a behaviour are numerous and obvious, with the most relevant ones lying on the stressful lives that most people from modern societies face. Even more, given the increasing mobility demand in many professional activities, it is also often the case that the patient cannot attend his medical meetings due to his diverse travelling appointments.

M.M. Cruz-Cunha et al. (Eds.): CENTERIS 2011, Part III, CCIS 221, pp. 371–383, 2011.

Of course that, when a patient has already experienced some effect of a heath problem he/she becomes more cooperative with the health system. But it is also not less often, that when such a time cames it is already to late, in the sense that precious health care time has already been lost. Therefore, a non invasively system oblivious to the patient that can measure a variety of parameters, and retrieve them to the physician for further analysis, would certainly improve long term patients health.

A third and important observation of the way patient monitoring is performed today, is that a considerable number of medical meetings that do take place are indeed superfluous. This happens mainly because there is no other mean, besides the physical meeting, for the physician to scrutinise the patient current state, or because the patient doesn't feel suitably accompanied by his doctor and has no other mean of getting medical feedback other than attending a traditional medical meeting.

Building up on top of all the already identified problems of health care systems, one may also add the waste of money spent on all the unnecessary medical meetings as well as the waste of time for both patients and physicians involved in such meetings.

Another relevant aspect of today's medical diagnostics and health treatments is that they are often solely based on objective physiological and pathological data, neglecting other important sources of information like the patient's style of living, his life events and human dispositions.

These intertwined psychological and social nature factors cannot be overlooked [7,5,2]. The traditional diagnostic information, although important for the maintenance of health and quality of living, is certainly not the most determinant. An ecosocial approach is needed. Inequalities in health are related with the family social level of the population as a whole as well as with the differences of people's lives and work conditions [4,1]. Thus, one should also be able to capture such factors and provide them to physicians in a useful manner can improve health problems diagnosis.

In order to cope with this problem and given the presented constrains, we propose a rule-based mobile system called *Medicis* that delivers an easy to use mobile solution for the patients and a powerful desktop platform for the physician.

The mobile solution is intended to be used by the patient and it targets the delivering of important medical information from the physician to the patient as well as a user friendly interface permitting the input of several health parameters, requested by the physician, from the patient.

The desktop solution is oriented towards the physicians and it generally serves to suitably analyse the different patients collected data as well as to select new measurements for specific patients.

Contributions. We present a mobile patient/physician interactive rule-based system (section 2), composed of a mobile solution (section 3.1) oriented to the patients and a desktop solution 3.2 targeting physicians requirements. In order to bring communications demands to a minimum, a non-trivial synchronization process between the mobile and desktop solutions was implemented (section 3.4).

Addressing the problem of reducing the amount of information physicians have to deal with, an intelligent mobile rule based system was implemented (section 3.5). Finally, concentrating on the neglected recording of psychological and social nature factors, we have also implemented a personalised health record module working both on the mobile and desktop solutions (section 3.3).

2 Medicis Overview

Medicis is an health care solution with three main entities interacting with the system, namely the physician, the patient and the system administrator. The solution is composed of three main components: a mobile application, a desktop application and a middleware component responsible for all the data synchronization between the mobile and the desktop application.

The typical and resumed operational scenario for Medicis, is one that starts with a traditional physician and patient meeting. In this meeting the physician creates a new entry for the patient in the system and assigns him a mobile device with the mobile Medicis application installed[1].

After this initial meeting, the physician is given the possibility to register measurement requests, according to the patient specific health situation, that will be passed to the mobile application in order to collect instances of such measurements. The measurements readings, for which the mobile application is responsible for, can be performed by patient manual input or with specific sensors [8] that periodically interact with the mobile device feeding it with the requested data.

Besides all the standard patient information management (name, age, clinical history, etc), the physician may associate specific clinical rules, that will be passed to the mobile application for constant querying over the patient readings (the details of rules definition is presented in section 3.5).

On the patient side, when he logins in the mobile Medicis, the application gives him the possibility to update every personal data that his physician as access to. Even more, once in logged in mode, the mobile application will start asking the patient (or silently probing the health monitoring sensors) to insert values concerning the physician's measurement requests. At any time, a patient may consult diverse useful information about his present health situation, doctors advices and measurement readings.

Resuming the physician desktop application requirements, the platform allows the physician to perform the following actions:

- Consult and manage his patients personal and clinical information (fig 1);
- Manage the tradition meetings with his patients whenever he believes it is relevant to do so;
- Define new measurements for the patient to perform and submit the obtained values. This can be for instance, the blood pressure, temperature or heart beats per minute;

[1] Given the growing spread of mobile devices, it is expected that more and more patients use their own devices.

Fig. 1. Patient Information

- Inspect, with suitable visualisation techniques, the requested measurements submitted by the patients in answer to his measurements requests;
- Manage the *Personalised Health Record* (PHR) entries for his patients;
- Administer the rule based system running in every mobile instance, by creating, removing or assigning specific rules to a patient.

Following the same topic requirements enumeration, the mobile application provides the patient with the bellow operations:

- Update is own personal information;
- Submit specific measurement values in answer to the physician measurement requests;
- Insert new PHR entries, reflecting is psychological and social feelings at the moment;
- Read his physician's requests for appointments;
- Request appointments with the physician, referring some particular reason for so;
- Get feedback, either from the physician or from the rule based system, about every action he may have had with the application;

The mobile application holds two different working modes, namely an offline and an online mode. In the offline mode, every operation performed by the user or triggered by the rule-based system is stored internally with specific time and synch stamps. Latter the communication component will be responsible for interpreting this operational stamps and perform a correct information synchronization with the main system. On the other hand, when the mobile application is running under online mode, a direct connection to the main system is available. Therefore, every operation on the mobile application that takes place under such mode and demands an interaction with the main system, it is executed in the mobile device and immediately after it is replicated in the server in a transactional way.

The communication component is responsible for controlling the login process associated to each mobile device as well as for performing every data synchronization between the mobile devices and the main system.

In what respects to the login control, the communication component must be able to cope with the fact that a mobile device that is now assigned to a patient, carrying all the data and functional apparatus for the current patient, may become assigned to a different patient in the future. Even more, such an identity change must take place silently, whenever a different patient is able to login successfully in the application.

Facing such a loose identification scenario, the communication component is responsible for synchronizing the previous patient information and preparing the entire mobile application to start serving the new logged in patient. Moreover, the communication process is also capable of maintaining coherent and updated information concerning measurement requests, measurement values submissions, PHR entries, appointment scheduling and most of all, delivering and installing correctly all the rules from the rule based system running assign to the current user.

The next sections explain in some detail the most relevant parts of the Medicis solution. In particular, one presents the entire system architecture as well as the implementation of the major components inside each application.

3 System Architecture

The architecture of the developed solution is composed of 4 main modules: a mobile application, an ASP.NET Application, a Windows Forms Application and a Main System that acting as a server providing several services for the remainder modules.

Each of this modules is further divided in more fine grained components, as depicted in figure 2.

The main system module is composed by the standard Data Access Layer and Business Logic Layer, which provide isolated data base access and entity management operations respectively.

As explained in the previous, the communication component is responsible for checking all the incoming data from the mobile application, and guaranteeing that the main system keeps coherent and synchronized data about the mobile users.

The PHR component, is responsible for managing the Personalised Health Record operations that are presented in section 3.3.

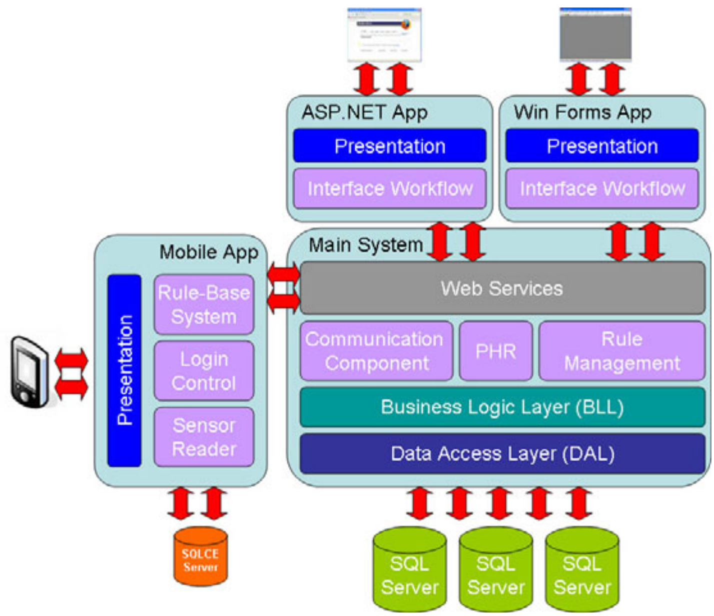

Fig. 2. System's Architecture

The Rule Management component controls a repository of available rules and permits the creation, deletion and update of rules inside this repository. Ultimately the rule repository is materialised in the SQL database, where "if then else"-like rules are stored in a relational manner.

On top of all this functional components, there is a web services layer that makes use of all underlying layers in order to provide specialised services for the different application modules.

The mobile application contains a Rule-Based System component which performs basic rule management as well as a constant verification of rules appliance, based on the data collected by the sensors or the user. The details of the internal mechanisms that handle this operations is given in section 3.5.

The login component, which is another constituent of the mobile application, is in charge for setting up the mobile environment for the user currently logging in, as explained in the previous section. The mobile environment is composed of diverse patient specific information, like personal data, measurements, rules, medical appointments, etc.

The sensor reader component is a small library that interacts with the mobile device COM port for the retrieval of information captured by the medical sensors the patient is carrying. This component acts basically like a selective parser, depending on the sensor it is reading, over the data stream that arrives at the mobile device COM port.

Since most mobile devices do not provide a COM interface, one has chosen to use a COM to Bluetooth converter in order to allow COM communicating sensors to be connected to the mobile application. Once the sensor is connected to the Bluetooth antenna component, the mobile device is able to intercept the wireless signal from the sensor, which is then associated to a COM port on the mobile device.

With this combination of sensors with bluetooth antennas, this probing devices do not have to be physically connected to the mobile device anymore. Thus, the patient may carry a series of this wireless sensors in a very comfortable manner.

The wireless sensor prototype that we have developed as a prove of concept, makes use of a "Parani ESD100"[2] Bluetooth antenna and a COM interface thermometer. Although the size of the developed prototype sensor (about 6 by 4 by 3 cm, excluding the battery) makes it a bit uncomfortable to carry, perspectives are that it can become much smaller with the appropriate support from digital circuits companies.

The Interface Workflow components are responsible for maintaining a state for the the diverse user interface processes that take place in the respective applications. Finally, all the presentation layers in the user interface applications are responsible for generating the graphical user interface for each scenario.

3.1 Mobile Solution

The mobile application was developed to address patient requirements in a mobile scenario. It was developed using Windows Mobile 2005, the .Net Compact Framework and Microsoft SQL Server Mobile Edition.

Several useful features to the patient were implemented, such as the possibility to manage the meetings that are scheduled by the physician, verify and update personal information, register measurements of parameters and the insertion of PHR episodes.

The application also permits the patient to actively request new medical meetings, receive new electronic medical prescriptions and synchronise data via a call to the communication component.

the main goal during the mobile application development was to provide an easy way for patients to understand and work with the application, by giving it a visual and intuitive interaction mode, which can be inspected by the screen shoots of the application.

All the application data demands are provided directly from the mobile database which is kept coherent by the previously presented Communication Module.

The following figures present a brief screen shot overview of the application, with main menu screen (Fig. 3(a)), the form to introduce a new parameter measure (Fig. 3(b)), and also the rule-based system in action (Fig. 3(c))

In what concerns to health monitoring measurements, every parameter request has a time interval, and a periodicity. whenever a measurement request expires, the interface guarantees that the patient cannot submit any more measurement values for that parameter.

[2] Available at http://www.merlinbluetooth.co.uk/merlinbluetooth/parani-esd100-class-1-chip-antenna-p-92.html?osCsid=65bfefd0032dad3354ce2c422745bb90

(a) Main Menu (b) Insert Measurement (c) Mobile RBS

Fig. 3. Mobile Application

3.2 Windows Forms Application

The choice for using a windows application is due to the fact that the hospital unit or clinic needs a direct and privileged connection to the main system, which could not be achieved by any other application relying on a disconnected environment.

Like so, the windows application has been developed with a fair notion of usability, and the concern of providing the right data at the right time. All the administration tasks are available, like the creation, editing and deleting of patients, physicians and parameters. Other features such as the scheduling of new parameters to measure, an electronic medical prescription builder and a rule construction system are also available to the physicians.

All the data submitted by the patients is kept in the SQL Server database. The patient physician has access to this information by browsing the patient record. Here the physician can perform all the clinical management operations as depicted in figure 1.

The analysis of several different medical parameter values cannot be performed in an individual manner, by inspecting each parameter in an isolated scenario. In fact, many clinical parameters are related with each other and for the physician to analyse them suitably, it is of most importance that he should be given the possibility to relate different parameter measurement as easy as possible.

Addressing this problem, the Windows Application provides the doctor with the ability of selecting up to four parameters and with them generate several kinds of graphics for a given time interval. In figure 4 one can see such a case where different parameter measurements submitted by a particular patient are laid out in a graphic.

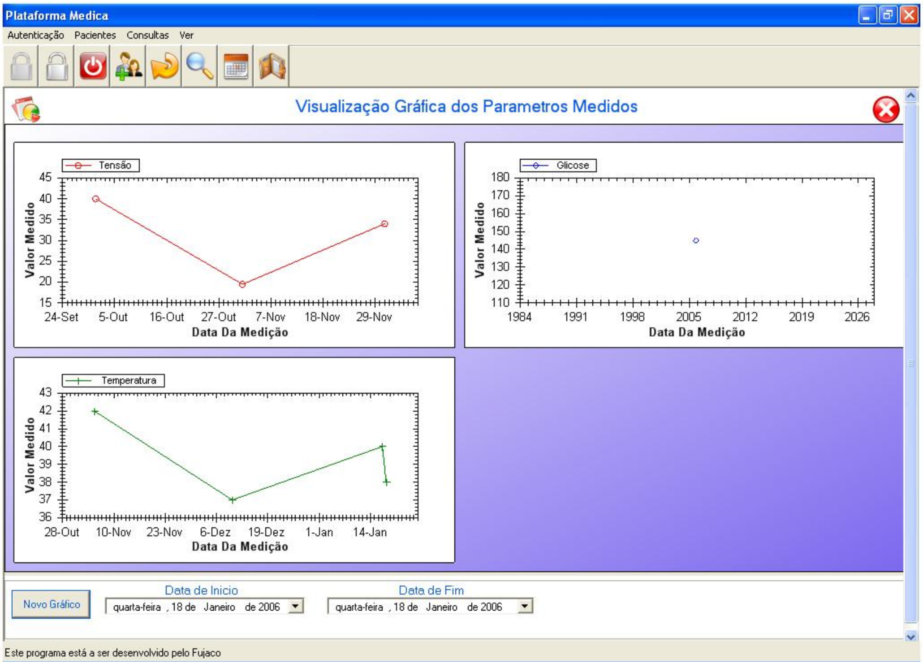

Fig. 4. Measurements Visualization

The Windows Forms Application also delivers a login process enabling the application to authenticate and authorise the users accordingly to their previously collected system permissions. One of the main purposes of such a login system is to control the specific information that users may or may not have access to. Just to illustrate the kind of policies that the systems allows to, it is not possible that a doctor consults information about patients that are not assign to him, nor can he send rules or measurement demands to those patients.

3.3 Personalised Health Record

Targeting the problem of capturing psychological and social nature factors from the patients living reality, Medicis delivers a personalised health record module that follows the guidelines of recent medical research in the area.

Based on a long standing clinical family practice both in outpatient hospital clinics and private practice Machado H. [6] conceived a module that is the expression of a collection of symbols (Fig. 5) related with the following aspects: Life styles, Life events, Disposition.

The module is made of four parallel lines onto which representative symbols of subjective elements are drawn. These are usually negligible on the standard clinical patient records in spite of their recognised importance. The aim of the

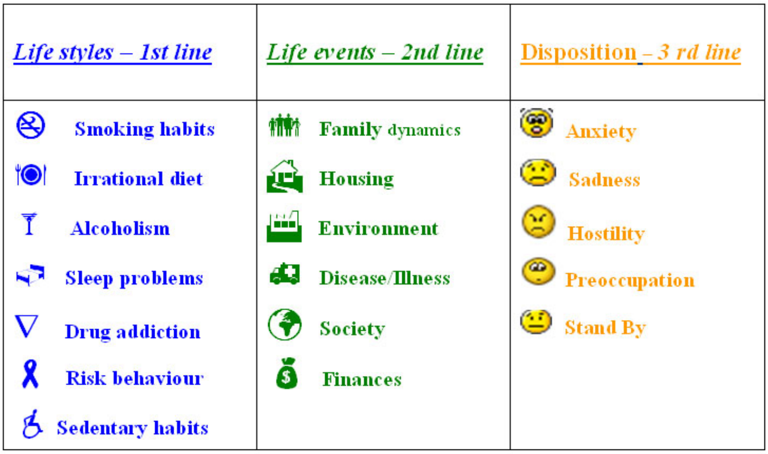

Fig. 5. PHR Symbols

proposed module is to humanise and personalise the medical record to ultimately attain measurable improvements in clinical practice.

Both the mobile and the desktop application are capable of submitting PHR entries into the system. Nevertheless, entries that came from the desktop application, that is from the physician itself, are marked differently from the ones received from the mobile application which where introduced by the patient. This simple labelling of PHR records will permit the physician to give different confidence values to each of the input PHR entries in order to predict specific health problems.

On top of these user friendly PHR entries registration, the desktop application also delivers suitable visualisations of all the submitted PHR entries for a particular patient. In particular, it is possible to inspect all the four lines at the same time, compare them and even navigate to the detail of a specific episode occurred at a particular point of the patient's life.

3.4 Data Synchronization

One of the main problems in developing a mobile application, providing an offline mode, is certainly that of data synchronization.

In most mobile applications, the synchronization is done via web services and to do so, the mobile device need to be connected to the internet. This limitation is of great inconvenience for the user, so we have opted to developed a solution that supports an online and an offline mode of operation.

By using SQL Server Mobile Edition to store data in the mobile device, the user doesn't need to be connected to the Internet because all the data is stored in the database. SQL Server Mobile is a relational database engine, with similarly features and types as the SQL Server 2000, so synchronization is easier with these two databases engines.

By logging in into the mobile application in online mode, the application perceives that there is a remote connection to the central system and starts synchronizing data automatically. The data to be synchronised is marked with a flag, so that the system knows exactly at each time what data has to be send, avoiding this way, large amounts of data communication overhead and possibly even avoiding the creation of invalid replicated data.

The mobile application sends to the windows application, different kinds of data like new parameters measures, new PHR measures, personal information updates, and medical meetings requests. On the same synchronization event, data is also sent by the windows application to the mobile device, such as new parameters to measure, scheduling of new medical meetings and new rules to the patient rule based system.

There is also the possibility for the patient to start the synchronization in an active way. By accessing the respective option, the patient may actively send or receive fresh data from the hospital unit whenever he thinks is relevant. If the clinic or the hospital unit provides a PDA or another kind of mobile device to a new patient, the entire data download and personalisation of the application to the patient in question is also performed by this synchronization process. Because different users can use the same mobile device, to change user, only new authorisation and authentication (username and password) credentials are required.

3.5 Mobile Rule-Based System

To improve patient experience and to give the mobile application even more flexibility and intelligence, it was implemented a rule-based system (Fig. 6). This mechanism provides the doctor a way to automatically monitor certain parameters and also filter information in different manners.

Rule-based systems are adaptable to a variety of problems. In this case, information is provided by the patient and comes as parameters measurement, PHR measurement and other types of input information. The rule-base system analysis this inputs, determines the possible rules to fire and also where they lead.

Our working memory is composed with different kinds of facts and also facts that result from the firing of other rules. Our approach to implement such a solution was to use a forward-chaining, data-driven, system that compares data in the working memory against the conditions (IF parts) of the rules and determines which rules to fire. It is the doctor responsibility to build this rules and the respective action to fire.

The deployment of these rules to the mobile device is done each time the patient synchronises data. For example, if the doctor sets a rule to be fired when the cholesterol passes over the value of 300 the action could be a warning to the patient or even as SMS or email to the doctor. This way, the patient is being monitored all the time, and the doctor can be notified if a certain parameter or a set of facts fire a determined rule.

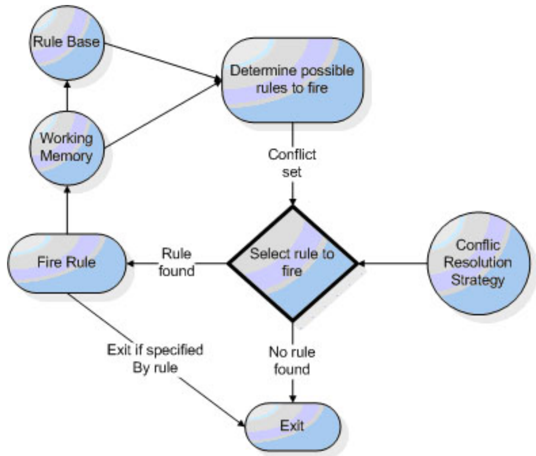

Fig. 6. Rule Based System Architecture

It should be mentioned that this rule base system in running on every patient mobile device, becoming the first rule based system reported to work on a pocket device at the time of writing. Given the specific constrains of both the compact framework capabilities and the limited processing and storage power of pocket devices, this component demanded great work and constant adaptations during development time.

4 Conclusions and Future Work

We have presented Medicis, a health care solution that tries not only to improve the relation between physicians and patients but also to improve the quantity and quality of clinical information a physician may have at his disposal.

Medicis is a cheap and feasible solution with great results in both time and cost reductions from the patient, the physicians and the entire health system sides. In fact, the cost of implementing such a solution passes only by a desktop computer to be given to the physician (which is already a common reality in many health care centres), a mobile device to be assigned to the patient (given the growth spread of mobile devices and the constantly reducing cost of such devices, this does not represent a significant investment) and a mean of communication, which can range from the more expensive GSM networks to the cheapest slower modem connections.

Given the short time between the final implementation of the system and the time of writing, there haven't been any real case test of the entire system. Nevertheless, the entire development phase as well as the major implementation decisions were followed by experienced physicians that gave important feedback to several aspects of the solution.

An interesting topic of future work would be to develop a self learning mechanism implemented in the mobile applications. Such a mechanism should be able to adapt the mobile application to the patient it is assign to, so that for instance, if the measurements of the patient indicate that he his diabetic, then the mobile application should for instance privilege the measurement of glucose.

As a final point of future work, it would also be interesting to implement a common rule data base in order to be given access to every physician using the system. This way, a physician could inspect these data based for some pertinent rules concerning a particular patient of him instead of having to create the rules for every new scenario he faces.

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A User-Centered Approach for the Development of a Pervasive Mobile Tool for Health Care

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Abstract. The medical assistance is an area that is in constant adaptation to the technological advances in the last decades, specifically in communications and information technology. Telemedicine has been following the growth of mobile and wireless technologies promoting a broad medical care and self-care access to patients with difficulties. However, several challenges still hamper the acceptability of solutions that offer treatment aid. The adaptation of technology to the patient's everyday life in a noninvasive and secure way are some of those challenges. In order to minimize these problems, the development of a mobile tool for medical assistance based on a User-centered approach and communications standards is proposed in this paper.

Keywords: Pervasive Computing, Pervasive Healthcare, User-centered design, Mobile Applications.

1 Introduction

The management and monitoring of clinical information from patients through the usage of computer systems is a way to facilitate and accelerate the health care in several contexts. However, in routine consultations or treatment of critical diseases the patients usually do not manage their clinical information, or the health institution that is attended does not use technologies that can assist in the patient care and can hinder the understanding of the patient's medical diagnoses. The use of technologies that aid the medical assistance may help the patient manage his clinical obligations and to better understand his health condition.

Technologies to assist the health care may be used in different ways, resulting in infrastructures with mobile devices, embedded software, and wearable computing [3]. In this paper, we prioritize the patient mobility by the development of a tool for mobile devices, instead of the monitoring a specific environment, such as technologies at home [4]. The chosen approach allows the tool manipulation by a diverse target audience anytime and anywhere, for instance young persons, elderly, people with different deficiencies and schooling [6].

M.M. Cruz-Cunha et al. (Eds.): CENTERIS 2011, Part III, CCIS 221, pp. 384–391, 2011.

The proposed tool is responsible to perform critical procedures (e.g. recovery and sending clinical information in a health critical situation) to the treatment of patients with chronic diseases, thus it is necessary its validation in order to ensure the dependability of the tool. Therefore, we performed the formal modeling of some features with Coloured Petri nets (CPNs) using the CPN Tools [20].

In this paper a pervasive solution for mobile devices in order to monitor clinical information of patients is proposed. The paper is structured as follows. In the Section 2 concepts of the Pervasive Healthcare are described. Section 3 discusses concepts of the patient centered design. In the Section 4 the proposed tool and a participatory development process are presented. In the Section 5 future works are introduced. Finally, Section 6 concludes the article.

2 Pervasive Healthcare

The pervasive computing paradigm each day is becoming a reality, because services may interact with devices dispersed in the environment, performing actions by context-awareness. The use of this paradigm allows a transparent interaction between human and machine [5], for instance through wireless sensors, wireless networks and Bluetooth.

One of the most important sectors which the pervasive computing may be applied is the aid to health care, including support of preventive and emergency care [7]. In the context of Pervasive Healthcare applications, several kinds of infrastructure may be used, including electronic devices with embedded software and wireless sensors placed on the human body [8]. This may be implemented in specific environments such as hospitals, homes or smart devices integrated in patients' everyday life.

The main goal of the Pervasive Healthcare is to provide medical assistance anytime, anywhere and independent of the availability of health professionals [9]. These professionals need access to patient information as well as submit their own conclusions about his current health situation [10]. As an advantage of the usage this kind of system may be the patient situation visualization through several view points in the retrieval of a set of conclusions and opinions of different professionals.

3 Patient Centered Design

A User-centered design approach consists of the user participation in the project, from beginning to end of the product development [2]. This includes the phases of data collection, development, deployment and testing. The use of this approach is able to provide the creation of products that really supply the expectations of their end users, and may increase their trustily and security.

One sector that may be enough benefited by the participatory development is the health care [11][12], in which a Patient-centered design may be performed to create Patient-centered applications [23]. Pervasive Healthcare Applications manipulate information about the health situation of patients. Consequently, the data security is a relevant factor to be addressed in their design phase [16], because it is one of the reasons that may cause a decrease in the acceptance of users to use the system.

To create solutions that supply real needs of patients, to help in improving their quality of life, and also increases its possibility of acceptance, it is important to conduct a detailed analysis of the problem addressed and a well-defined project. In this context the realization of a Patient-centered design can be an important approach for achieving the intended objectives. This participatory approach can involve not only the users of the solution as mentioned above, but relatives, friends, or anyone other person who participates in the patient care [17], what provides a better understanding of his treatment.

The development of solutions to health care based on a Patient-centered design are very researched, in which may be identified several important aspects, for instance usability, user acceptance and security [23].

4 The Developed Tool

The tool proposed in this paper is a solution to health care support through mobile devices, it is developed using the Qt framework and programming language C + + [13]. The recording of information in the tool is performed by the SQLITE library that is a compact database which provides simple data persistence without the necessity of configurations [14].

In the context of management information, the tool provides the control of users, medicines with the alert of times and dates, allergies, vaccinations, physicians, health plans, health problems, clinical procedures and clinical results. The tool also offers the sharing of clinical data with physicians in a moment of a routine consultation or an emergency treatment.

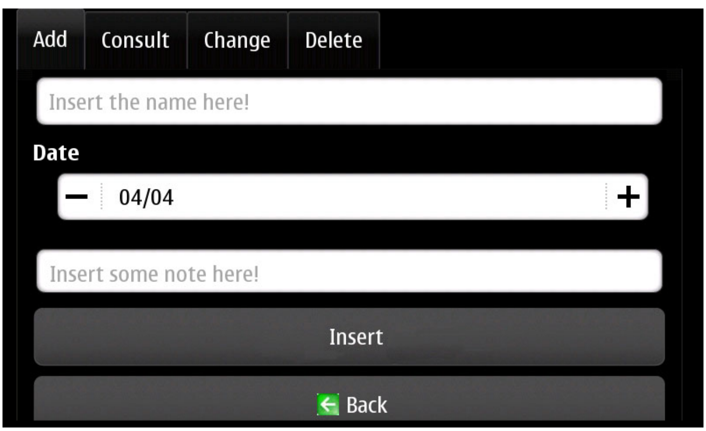

Fig. 1. The user interface for vaccines record. The options for handling records are divided in tabs to improve the usability of the tool.

In order to perform this proposed of information sharing we are studying the use of the HL7 Clinical Document Architecture (CDA) and openEHR standards. The HL7 CDA is a standard for clinical documents used for the purpose of exchanging information [1] and constructed in the eXtensible Markup Language (XML) format. The openEHR is the standard of specifies mechanisms for interoperability between healthcare applications [15].

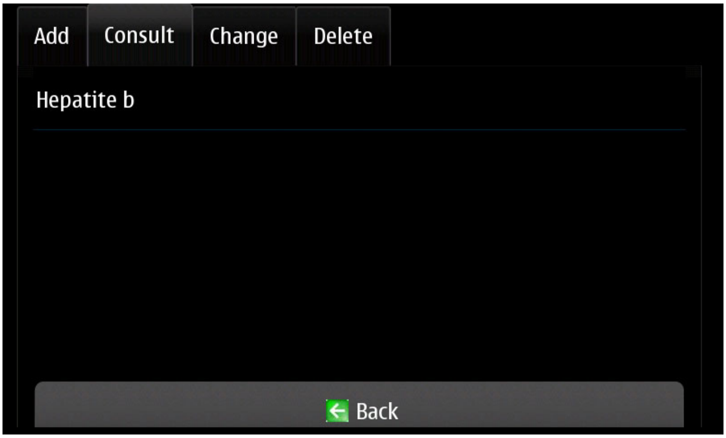

Fig. 2. The user interface for vaccines consult. By clicking on the "Consult" tab the tool lists all vaccines registered before.

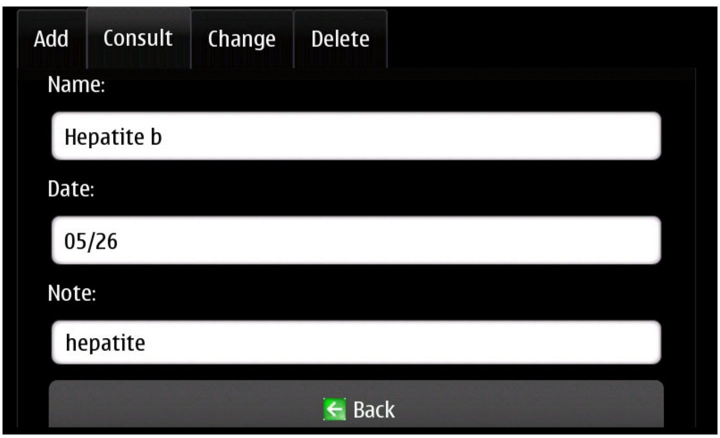

Fig. 3. The user interface of a vaccine result of the tool. The consult is performed with a simple selection of one of the vaccines listed before.

4.1 Use Scenarios

The proposed tool may be used in several contexts aiding in the patients care. To illustrate some these possible scenarios that patients may benefit by using the tool are described. A first scenario that we presented is the collaboration of clinical information between patients and physicians, which in a simple consultation or an emergency service, fragments of the patients' Electronic Health Record (EHR) are needed to provide health care and also to help avoid possible lack information in a verbal communication.

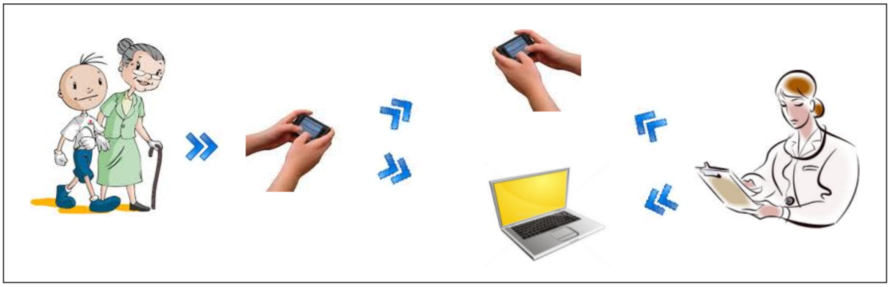

Fig. 4. A scenario of ad hoc information sharing between patient and the physicians that perform his care

In a second scenario, the tool may be used as a manager for the intake of medicines. By using the tool, patients can register their medicines in a dynamic way (e.g. we aim to achieve the communication tool with the Google Health system [19] and use its database of medicines) or it automatically register the medicine when receive a prescription in a digital form. Finally, in the moment of need for medication intake the patient may be alerted in a visual and sound manner.

4.2 The Patient-Centered Approach

In the tool development a participatory approach involving patients with chronic diseases and physicians is used. This process is based in a Patient-centered design, in which is being performed a field research in a Brazilian hospital in the state of Alagoas, with the observation of the patients' treatment, interviews and usability testing of the tool with patients and physicians that perform their care.

Currently, we are performing the interview process and usability testing of a prototype tool. This has enabled the analysis of initial results and is helping to orientate the research to aid of patients with specific clinical situations. In this paper are described some of these results that we consider relevant in the context of this research and the future direction of research is presented.

As initial results of this approach the need to improvements in the tool and some good points are highlighted. Suggestions for improvement such as the record remove of the health plans for security reasons and inclusion of the National Immunization Program (NIP) table of the Brazilian government. As positive points the control of medicines and vaccines were highlighted because they are important information in a time of clinical emergency.

In the process of Patient-centered design that is being performed we are identifying the need to help the care of a specific set of chronic patients. By choosing this focus we consider a specific clinical treatment that is affected by diseases that have high incidence in Brazil. Thus, this work will conduct a study of how to help the treatment of renal diseases in patients who have diabetes and/or hypertension.

4.3 Medicines Control Modeling

To perform the validation and generate a documentation of the tool presented in this paper, the modeling of some resources is being performed using Coloured Petri Nets

(CPNs). CPNs is a systems modeling language that uses programming resources in Petri nets models [18]. CPNs provides a graphical representation for systems modeling (e.g. transitions and places), a simulation of the model by the CPN Tools, and also the use of the functional programming language ML [21].

CPN Tools is a set of tools that provide an environment for the use of the CPNs language enabling the creation, analysis and simulation of the models [22]. The CPN ML is based in the ML language and offers resources for the use of data types, parameters and data manipulation in CPNs models [18]. With CPNs several kinds of software system can be modeled, which may include asynchronous and concurrent features [21].

The motivation to accomplish the modeling of the tool with the CPNs language is the possibility to ensure its proper operation to perform simulations to verify its behavior and thus improve its functionality. The reason for this concern with a formal modeling of the proposed tool is because it handles critical information and procedures to patient care, where errors may result in complications for his health condition.

As a motivation example we can highlight the modeling process of the data exchange between different applications, in which some procedures proposed by communication standards (as described above HL7 CDA and openEHR) could be validated. This validation may be useful in the sharing clinical information of patients in an emergency service, for instance, the data exchange about allergies from a patient that needs of a drug intervention or that requires an anesthetic procedure.

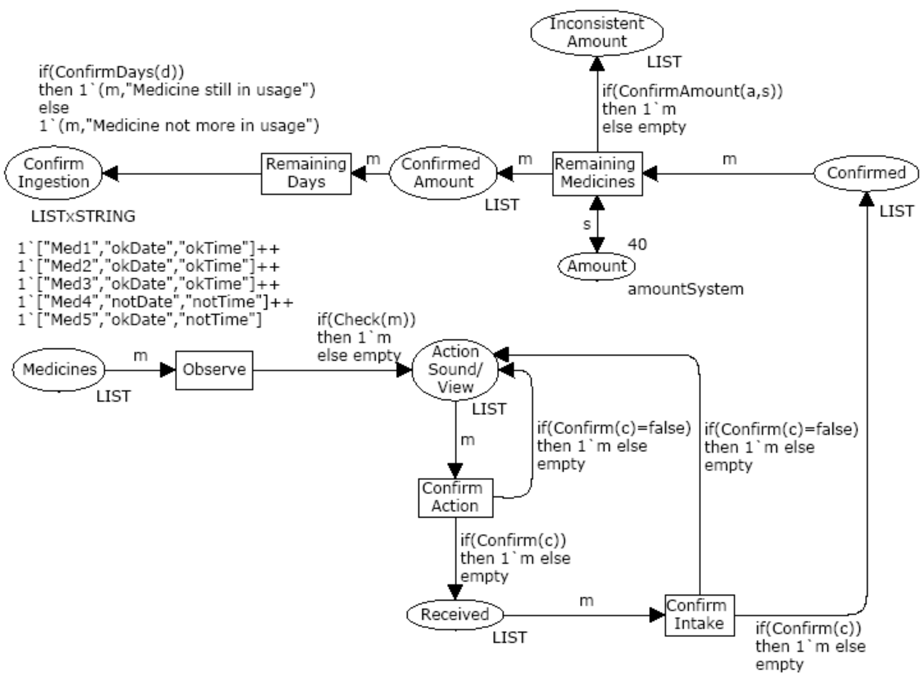

Fig. 5. Coloured Petri Nets model developed with the CPN Tools to represent the procedure of control of medicines from chronic patients

The application process of medicines control is shown in Fig. 5. In the initial state of the model, the medicines date/time is verified, and the sound and visual alert are triggered. Thereafter, the tool solicits confirmation of the alert visualization and medicine intake. To control the remaining medications in the tool and what the patient really has at home, an amount confirmation of medicines is solicited. Finally, the amount of remaining days and the medicine usage state are shown.

5 Future Work

As future work the tool proposed in this paper can be integrated with some services provided by the Google Health system [19]. Another extension is to focus its management and monitoring information to assist patients with diabetes and hypertension in the renal disease treatment as mentioned above, and to perform the communication with wireless sensors (e.g. blood pressure). Finally, the continuation of the tool modeling by usage Coloured Petri Nets is desired.

6 Conclusion

The use of Pervasive Healthcare applications to monitoring and management clinical information of patients may be a way to assist to improving the long-term health. It is also the possibility of a reduction of financial costs and guarantee care to low-income users, for instance, performs remote consultation, avoiding the need to go in places of difficult access.

The proposed tool in this paper has the possibility of facilitating the everyday life of its users, offering mobility and providing medical assistance anywhere, anytime, without the need to perform certain actions explicitly and also sharing their clinical information with health professionals.

One of the main results with the participatory approach that is being conducted in this research is a better understanding of the real needs of patients in which as mentioned before is directing the study to assist the treatment of specific patients with renal disease who have diabetes and/or hypertension.

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mULCER – A Mobile Ulcer Care Record Approach for Integrative Care

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Abstract. Mobile applications are increasingly used to support nursing work. Specifically, mobile information and communication technology (MICT) has potential to support treatment initiatives in patients with skin ulceration or a high risk for their development. We propose a mobile ulcer monitoring system - mULCER – which serves to control patient's ulcer status during all stages of treatment. Additionally it integrates with an electronic health record (EHR) system. mULCER synchronizes ulcer data with the EHR and provides an everywhere every time support for nurses on evidence-based advice for prevention, classification, and monitoring different phases of ulcer healing or prevention. It also increases security and extensiveness of nursing record. The solution can be operated in stand-alone mode or embedded into an EHR system. It serves as a tool to integrate nursing care among hospital departments and institutions on an enterprise wide effort to increase level of health care integration at the point of service. The advantages and disadvantages of mobile devices for this purpose are also discussed. The paper describes the concepts and includes a prototype to demonstrate the proposed contribution.

Keywords: Mobile health, mobile application, ulcer monitoring, nursing, Android.

1 Introduction

Aged or severely incapacitated patients, often present reduced mobility (either at home or in hospital) which increases the risk for developing pressure ulcers. These are uncomfortable, add co-morbidity, and represent additional costs to hospitals and other health institutions [1-2]. In addition to ulcer prevention, optimal care can help avoid deeper wounds [3]. Other types of ulcers, like venous and arterial ulcers, are becoming increasingly frequent as diabetes, heart failure, and age related vascular damage raise significantly in elderly populations. These may mean differences in nursing care strategies, but overall pose similar needs for follow-up and record

M.M. Cruz-Cunha et al. (Eds.): CENTERIS 2011, Part III, CCIS 221, pp. 392–401, 2011.

keeping. To increase quality of care while reducing costs, nurses and managers focus in two main strategies: i) protocol based approach to ensure homogeneity and standards of care, while structuring costs with materials and ii) ensuring effective use of expensive ulcer care consumables. Many institutions have their own ulcer care protocols that span from classification to treatment suggestions. As first example, the Braden Scale protocol that helps to evaluate the patient risk on developing a pressure ulcer. Another example is the skin breakdown prevention protocols that are inspired in indications of the agency for health care research and quality (AHRQ) [1-4]. The treatment process may also involve patient and patient family education; such guidance can also be incorporated in a treatment protocol-approach.

Protocols chosen by institutions are normally in a printed paper form and stored in some folder to be consulted in a case of doubts, but usually far away from the bedside or the patient home. Even when information available in protocols is good, difficult or deferred access may significantly reduce its capacity to impact on behavioral and knowledge aspect of ulcer care. A pressure ulcer management protocol like the one described in [5], includes images showing the layers of the wound, real images of pressure ulcers or wounds, and other important information like its main characteristics, presence of exudates, and recommendations for treatment. However, this protocol can often be found on a nurse room wall, but it is more helpful and practical to have it close to the place where a care is provided [6]. MICT can be used to deploy such guidance via mobile phones ensuring that access to the information becomes ubiquitous and in real time [7]. In addition, the camera capacity, widely available in such devices, has reached resolution levels that allow its use for convenient photographic recording of ulcer/wound status. This can be enhanced by scoring systems and structured recording. The relevant information can be linked to the patient (such as last treatments or previous ulcer occurrences) that depends on effectiveness and quality of wireless communication [8].

While many EHR, and some commercial versions of software for nursing care [9-10] may share some of these features, they often lack flexibility for use in MICT, like Android-based mobile phones, they are often limited in their use range by institution policy or licensing and thus, a patient who is discharged from hospital, may come to have records of its ulcer care stages in more than one electronic system. In the systems referred in [9-10] also normally miss treatment suggestion, and ulcer monitoring by photograph. The proposed system takes also advantage of the photograph capability, to register the ulcer/wound status in order to make a better treatment decision in the future, mobility capability to allow the fast access to relevant information such as protocol or previous wound records, making like this the ulcer records more reliable with less time usage because are made on real time during treatment.

Simple and specific solutions for healthcare are often missing from the general consumer market and could come to benefit from its fast-paced development dynamics. This is the case of mobile applications for ulcer monitoring protocol information guided integrated with Electronic Health Systems which are rather specific and often not found relevant by large EHR companies. To our knowledge an ulcer monitoring and education system, is not available for android platform.

The reminder of the paper is organized as follows. Section II focuses on mobile computing available solutions and presents related work about EHR interaction.

Section III addresses the system requirements, showing the application architecture and the used technologies to create the application, while the system evaluation and validation is presented in Section IV. Finally, Section V concludes the paper and points further works.

2 Related Work

2.1 Mobile Computing

Mobile devices have attracted a huge interest of software development in large scale and there are many areas benefiting from MICT devices usage and adaptation to particular needs [11]. Important services to population are being deployed via MICT in several areas like education, tourism, business management, or budget control [12].

These devices may help interaction between people, in general, or among groups, such as, in schools among colleagues and in companies between employers and managers. Mobile computing, in general, tends to accelerate and facilitate the access to information, resulting in higher productivity.

The healthcare area is not an exception. For instance, inside a health care facility, a doctor or a nurse potentially benefit from the use of a MICT such as a Personal Digital Assistant (PDA) or a tablet computer equipped with medical applications that can help them for measuring, recording the patient's condition or providing real time access to relevant information.

2.2 Electronic Health Records Interaction and Related Applications

Large investments have been done into exploring the potential of mobile solutions to support healthcare services [13, 14]. The need to support mobile clinical practices and make health information increasingly more available to patient and professionals continues to stimulate mHealth solutions development. Examples span from hospital-based services for patient care to educational programs made available on mobile platforms with the intention to combat the epidemic rise of obesity and diabetes [15].

To improve the services of searching and locate clinicians the Qatar government developed a smartphone application for that purpose. In the United States, the Veterans Administration, known for its extensive EHR, also presented a mobile application that permits patients to access a central account, allowing the download of their health information, fostering information sharing between health care providers. These, and other, usages of MICT will only expand as society learns to act and react to mobile computing and harvests investment on mobile platforms, such as Android®, and communication capabilities [16, 17].

3 Ulcer Monitoring System

3.1 Architecture and System Requirements

The system architecture of the proposed ulcer monitoring system is illustrated in Figure 1. It includes an EHR, a File Repository and a group of smartphones carried by nurses or other health care users. Each smartphone has the mULCER application installed. This application keeps the files on a file repository database which can then be integrated to any hospital EHR system.

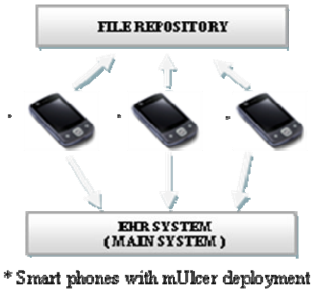

Fig. 1. Illustration of the mUlcer system architecture

An EHR may be defined as an information system that allows the integration and centralization of clinical patient processes which holds all records for each patient episode as well as those created via the mULCER application. This application also writes on a database on the main system where all mULCER records are synchronized and linked to EHR patient information. The file repository is a system that stores and keep organized the documents and pictures. The mUlcer application creates ulcer records associated to a patient in a given time and date, regardless of the administrative episode, such independence allows the mULCER application to remain usable when patient is discharged from hospital and the "episode" ends. This requires patients are always identified via a national health number (called in Portugal "número de utente") of which a national database exists, as well as, via a hospital number. After this registration occurs and patient is created at the database level, a document with relevant information is generated and sent wirelessly to the file repository in order to keep a resume of ulcer patient episode treatment. The information that is saved after each ulcer monitoring episode is synchronized with the main system by user order on mobile application. At the end of the synchronization process each mUlcer device application synchronized gather all information registered in the main system. This synchronization can occur at any moment of the ulcer monitoring process.

Figure 2 shows the architecture of the application. The mULCER application may be described considering the following main four blocks: the synchronization block, the application management block, the graphic user interface block (GUI), and Database block. Briefly, the GUI module allows the user to interact easily with the system. According to this interaction the Application Management module uses the Database module to store data. In the Main System the file repository module and EHR system are updated by the synchronization Module with files or records respectively.

The synchronization module is composed by an Application Programming Interface (API) to assist in two main functions. First, to synchronize ulcer records existing on the mobile device with the EHR System. Secondly, to post and get ulcer monitoring pictures and resume episode files from file repository. On mULCER application, the database module may be defined as a database system that stores all records that are involved in the classification, treatment and monitoring of the ulcer/wounds and an API to interact with the database.

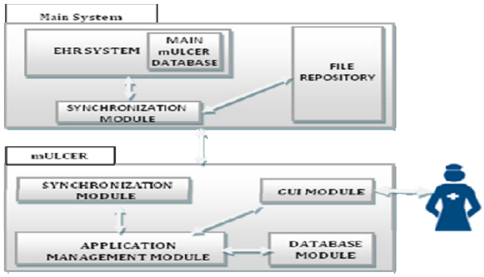

Fig. 2. Application architecture

As explained before, the file repository is where all documents generated by mULCER (including images taken) are kept. Considering the limited storage space of a mobile device, it is fundamental to assume the usage of a Document Management System (DMS) in order to improve the solution. This can save the generated files and ulcers/wounds images taken through the smart phone. This frees up space storage in the mobile device allowing that just ulcer records and lower resolution copy images are stored locally permitting ulcer records access without wireless connection. The GUI module defines the methods that are available for interaction between the users and application. Finally, the application management module coordinates and manages the interactions between all modules. Each action made by the user is evaluated by this module and assure that the correct module respond to the request. The mULCER application allows users to work at areas with any wireless connection interacting with a user-friendly interface. The application should be installed in each mobile device and registered in the main system(s). The system is able to display the contents that are saved locally. Thus, it is assumed that smartphone or PDA (personal digital assistant) works in standalone mode independently of wireless connection.

Following Fig. 3, the Health Care Provider may choose between four functionalities: i) Ulcer treatment, forces the user to search a patient between a patients list that are already registered in the system. Then, the user must register Braden Scale evaluation and register the treatment to the patient ulcer/wounds. Facultatively, the user is able to see a suggested treatment to a specific wound according with protocol information or read the latest treatments applied to the patient. ii) Alert the user for pendent tasks related with ulcer treatment to the patient. iii) Search data in documentation with protocol ulcer information. iv) Synchronize patient records with the Hospital EHR system that have the patient records. These options are available after successful authentication, and are illustrated on chapter four where it is shown how the user interacts with the user interface.

Fig. 3. Use cases diagram with main functionalities of the mULCER application

3.2 Used Technologies

The mULCER application is designed for smartphones with any mobile operating system. The version under development is to run on Android 2.2. The applications for Android are created using an API similar to java developed by Google and Open Handset Alliance. The Android operating system uses Dalvik virtual machine that provides a platform-independent programming which allows the application to be executed in the same way on any platform, independently of hardware and operating system. The development environment to create the mobile application has the Android software development kit, the Eclipse IDE (Integrated Development Environment) with ADT (Android Development Tools). The tests to the application are made using the mobile device emulator that is available at ADT. Like this it is possible to test the basic features during the application development. This application is built on Java [18]. The data records on the mobile device are stored under SQLite database. Cryptography requires complex and heavy processing to provide encryption to database records inside mULCER application. This aspect for database encryption is nowadays being discarded. However, the synchronization method brings also a security issue on the communication between the mULCER application and the Main System. Data encryption on wireless synchronization is planned on future work but the algorithms were not defined yet.

4 System Evaluation and Validation

The system will be demonstrated, evaluated, and validated from a technical perspective through an example (case study). First, customization in order for interaction with a Hospital EHR system is ensured. With mULCER application it is possible to record and include in the EHR photos and data of nursing work at classification, treatment and monitoring of ulcer care. The system works at standalone mode independently of wireless connection or any system. Hereafter, are demonstrated general application functionalities and users experience in the mULCER application during validation process. The main usage functionalities of the application system can be described as follows. Left part of Fig. 4 presents a screenshot of the Login Window. Following Fig. 4, "1" the user starts the interaction with the application and appears this window. At "2", the user enters the login name to access the system, and on "3" corresponding password. From "4", the user has to choose the system to connect. When pressed the button shown in "5", is validated on the mULCER local database the username and password from the selected system. After successfully login, the application opens Main Menu shown in the right part of Figure 4, marked as "6".

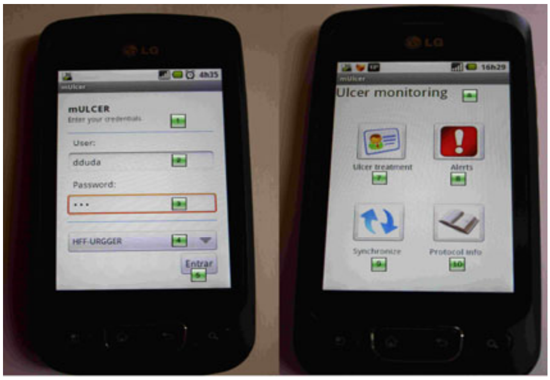

Fig. 4. Login Window and Main Menu

In this Main Menu there are four buttons. In the first one, at "7" in the ulcer treatment the user can select which patient wants to record. If it is the first patient episode the user inserts patient personal information, such as name, date of birth, hospital number, national health number and sex in order to create a patient record in the application. After the previous steps, appears the window marked as "1", Patient Record Menu, at Fig. 5. On "2" in this window is possible to register Braden Scale observation. The button marked as "3" can shows to the user a suggestion of treatment for the wound. When pressed, appears "6", Wound Picture Window. The user takes a picture to the wound when clicking on "7". Then, to go to "9", Wound Characteristics window should be pressed button marked as "8". On "10" can be selected ulcer categories from the list. On the list presented on "11" are the possible wound diameters. On "12" and "13" are the list of skin types and exudates quantity respectively. To be presented a suggested treatment must be filled the previous fields and pressed the button on "14". After that, appears the picture taken on the left side and on the right a roller with illustrative ulcer pictures. When user presses the correspondent image it matches both pictures, presents a possible treatment and suggest a reevaluation date. Coming back to "4", in order to register the treatment applied to the patient ulcers, this button has to be pressed. To read treatments applied in previous treatments to the patient, can be searched the document with this information by pressing on "5".

Fig. 5. Patient Record Menu, Wound Picture Window and Wound Characteristics Window

Coming back to Fig. 4, at the second button "8" on Main Menu, the user presses the alerts button in order to see the alerts for pending tasks. The alerting system warns and advises the user on the next steps and patient observations. There are three kinds of alerts defined. First, during the Braden Scale register, the user fills the date to next re-evaluation. Second, at ulcer treatment the user can specify the time of the next observation or treatment. The third one is generated automatically in the end of each treatment, according to the protocol time defined to turn around the patient. This protocol time is configured by central system. All three alerts types add to the schedule the date and time to alert, the task description and resumed patient details information. If the user needs to do a new task and wants to create an alert to it, the application gives this possibility in this menu. All data related with patients ulcer on Ulcer Treatment is saved locally. The third button "9", on Main Menu permits the user to synchronize the data records with the central system. Like this all registers existing locally are available in central system and vice versa. Finally, on "10" at Protocol Info button at main menu the user can search and read about medical relevant information topics. This information normally exists in paper but not available on the action environment near patient.

According the interaction to the application and data registered it is possible to evaluate it. With the positive feedback, means the fast access to patient and protocol relevant information taking part of mobile potentialities that makes work better, faster and with faithful data records.

Thus, the human error decreases, increase the usage of protocol relevant information on ulcer treatment, and ends ulcer registry method paper based.

5 Conclusions and Future Work

A new ulcer monitoring system is presented. The system is being developed taking into consideration clinical relevant information needs in the context of nursing work to classify, treat and monitor patient ulcers. The proposed mULCER application helps nursing work as well as other informal careers. A registry of ulcer status, treatment and monitoring are transferred wirelessly and easily integrated with any EHR system. Summarizing, in order to aid during classification and treatment ulcer steps it is available relevant paper protocol based information, with the possibility to record ulcers/wounds status with a picture. This picture would be stored at a DMS. This DMS also stores the generated files after each ulcer/wound treatment. The alert system was created to remember nurses on next treatments, on turn around patient task and next Braden Scale re-evaluation.

The proposed mULCER application can be integrated with any EHR system and its mobility opens new perspectives, such as, the possibility for its use in a primary care setting. It allows health care providers the possibility of keeping records about skin and ulcer care, even after hospitalization, on the same platform thus fostering continuity of care. It offers the possibility to follow all the process and provide treatment according to accepted protocols for integrative care and also provides information about what has been made on the patient immediately before. The idea is to make the application freely available to other institutions, in order to be used in the most health care facilities.

By compiling image and data of each step of care this application writes on a database which can be mined for research. For example similar problems (ulcer types) can be studied regarding the impact of different treatments approaches. Such can enhance ulcer care knowledge and foster better health care for patients with similar kinds of ulcers. In order to improve the security system of the solution it is evaluated the situation to encrypt the data that is synchronized with the mULCER application independently of the wireless connection used. In summary, this paper presents a mobile health application for ulcer treatment and patient risk evaluation in develop ulcers based on protocol information aided by pictures and integrated with an EHR.

This application can be improved with some changes, such as the ability to detect the measure, the length, width and depth, of the wound and also to suggest a possible classification after taking the wound picture. The development of both functionalities would make the system faster and efficient in the sense that the users do not need to make it manually accelerating the data registration process. Some useful functionality could be added as it is shown on [19], to improve the earlier detection of ulcer pressures by enhancing digital color images.

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A Founding Framework for Addressing Obesity in Qatar Using Mobile Technologies

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Abstract. This paper develops a founding framework for a comprehensive Obesity Management Program with Technology (OMPwT). There are two main objectives for such a program, namely – a) to trigger weight loss and effective behavioral changes that are reinforced through mobile and online technology support for users (overweight or obese patients) and their mentors (dieticians and clinicians) and b) to leverage technology to support an efficient workflow process and data exchange between users, mentors and the healthcare institution. We wish to do this in a local context of Arab gulf countries and specifically to Qatar. Our research questions are validated in small focus groups of physicians and dieticians. The proposed methodology covers the technological design of a comprehensive system that links all key players of the health ecosystem in a cost effective manner.

Keywords: Obesity, mobile technologies, e-health, information design, operational effectiveness.

1 Introduction

Over the recent decades, obesity and overweight have increased steadily and significantly not only in developed countries, but also, interestingly, in developing countries. In the latter nations, it is a result of the so-called nutrition transition [21]. In the Arabian Gulf region, Qatar has been one of the most rapidly developing economies. Therefore, the population of Qatar now suffers the consequences of rapid shifts in diet and body composition. Health studies suggest alarming numbers [19], [27, 24]. For example, [27] reports that 68.9% male and 78.9% female of a studied adults sample (25-64 years old) were at least overweight if not obese in Qatar.

Obesity can significantly reduce life expectancy and increase the likelihood of developing related diseases. In Qatar, the extreme environment (hot climate) may discourage outdoor activities which results in no or little physical activities [27]. Studies have shown that overweight and obesity can have devastating social and economic effects on the population level (affecting chances to get married, stopping education and lowering income). [4] Concluded that, for Qatari teenage girls, body image can lead to emotional stress and extreme dieting (i.e. fasting, slimming tablets, diuretics, laxatives, and or cigarettes).

M.M. Cruz-Cunha et al. (Eds.): CENTERIS 2011, Part III, CCIS 221, pp. 402–412, 2011.

Acting to alleviate the effects of overweight and obesity is becoming a pressing aim in Qatar [2, 22]. Through Obesity Management Programs (OMP) patients can achieve weight loss, but need support to maintain the loss. The objective of this research is to design an adapted OMP with technology to the region. The adaptation will stem from locally appropriate diet and physical activity plans, behavior modifications that use established social cum religious norms, appropriate health education and will leverage the benefits of technology advances. The program will use comprehensive mobile technology support to leverage patients' behavioral changes resulting in a serious health issue reduction and the provision of continuous support. Moreover, OMPwT will allow mentors to follow up on management plans (by accessing participants' plans and historical input) mentors following up with automated reminders and adapted responses to diet and exercise plans. Our aim is to develop a well connected simple, yet effective health ecosystem. We propose to support the adapted OMP with the usage of technology and specifically, mobile phones. Indeed, previous studies of technology usage in this context, using short message service, self-observations, visualization, and even gaming have confirmed some benefits in obesity management [12, 16, 18].

In this paper we first detail the objectives and significance of the research; we then present the current state of the art on obesity management programs and on technology assisted programs. We discuss some related preliminary studies and finally present the research design.

2 The Research Questions

Through Obesity Management Programs (OMP) patients achieve weight loss, they have difficulty maintaining it. As explained in Fig. 1, the current situation with obesity in Qatar leads to serious effects on patients and healthcare. In some instances telemedicine was used to improve the efficiency of such programs, in particular web-based or mobile phone technologies. Before developing such a solution, a study should be conducted and should provide answers to three research questions:

R1: Can we design and implement a technology that impacts the outcome of an Obesity Management program?

R2: Will the stakeholders welcome usage of technology as part of an obesity Management program?

R3: Is OMPwT cost effective?

To explore the relevance of such a research, we have first reviewed existing and culturally relevant programs to Qatar, then reviewed technology-based related and existing solutions and we have conducted a local study of interest. In the sequel, we present the results of these studies and a related design.

3 Review of Obesity Management Programs

Most successful programs use a multi-disciplinary approach with diet, behavior modification, exercise, social support and a societal change. As described by WHO

[24] in its ten facts on obesity, curbing the global obesity epidemic requires a population-based multi-sectoral, multi-disciplinary, and culturally relevant approach. For example, [6], relates a study of individual responses to food and indicates that there are ten neurophysiologic pathways that can lead people to make food choices subconsciously. Concluding that individuals have a limited ability to control food intake, the study suggests a societal solution to regulating the food environment. On the physical activity chapter, [7] conducted a systematic review of controlled trails of interventions in the case of childhood obesity. Interestingly, they conclude that nutritional education, nutritional skills training and physical education do not distinguish effective from ineffective interventions regarding reducing childhood adiposity. However, compulsory rather than voluntarily provision of aerobic physical activity resulted in effective outcomes. In [10], the Stanford experiments attempted to answer the question of how social movements can be used to fight obesity by addressing the deeper needs and desires of participants, their intrinsic motivators while improving health as a side effect. These are known as stealth intervention techniques. Experiments were evaluated on a group of undergraduate students at Stanford who followed a course on food related social and environmental issues. The students watched documentaries and read books on social causes. The experimental group improved dietary habits (e.g. eating more vegetables, fewer high fat dairy products and sweets) before and after the courses.

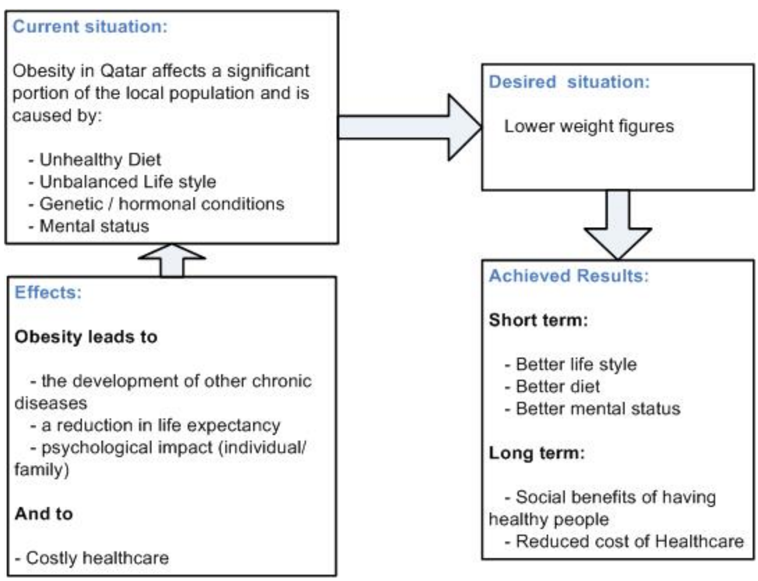

Fig. 1. Addressing Obesity Using Mobile Technology: Current to desired situation

In the context of Qatar and close neighbors, we are aware of studies that were conducted by Hamad Medical Corporation, the main hospital in Qatar: [19] discussed the social and psychological factors that result from overweight and obesity. Interviews with out-patients in Qatar were conducted and analyzed. They showed a higher risk for obesity among patients over 39 years, for females, for married patients, for higher educated and for those who watch television for more than two hours. This study was however not statistically significant and so results are to be taken with caution. In their next study, [20] analyzed body-shape preferences in Qatar. A sample of Arab women chose a more mid-range of body fatness for males than for females. This is a factor of interest in the choice of possible body representations in educational displays for OMPwT. [4, 5] conducted interviews of children and adolescents about dieting habits and social factors leading to obesity. Their results mention peer pressure leading to extreme dieting and excessive internet and television viewing as factors to obesity and should be emphasized. They relate studies that indicate a clear association between obesity and diabetes and highlight the importance of body weight control by diet and exercise as well as refraining from excessive smoking and avoiding consanguineous marriages. Other regional studies include the UAE University and partners [27] and the WHO regional office for eastern Mediterranean [13] with general studies on obesity in this region. They emphasize the need of conducting nationally representative longitudinal surveys to determine the factors leading to obesity in the gulf as most existing studies are limited in scope or sample sizes. Their study shows a comparable trend on obesity, overweight and resulting non communicable diseases in the Arabian Gulf states, including trends by gender and age groups. This suggests a possibility of a future extension of our proposal to the region.

Outcomes of this overview lead us to consider including a multi-disciplinary approach in our OMP research design: weight loss, attention to behavioral changes, provision of a social support, and inclusion of a longer term plan to maintain results.

We further review relevant studies where technology was used for weight management.

4 Preliminary Study of Technology Design

Telemedicine has over the years grown in interest especially for healthcare providers who seek cost-effective services for a growing population and shrinking resources. Systematic studies relate hundreds of publications in this area. In one systematic study, various telemedicine studies between 1990 and 2005 and give a special focus to studies based on theoretical concepts. Of the eighty three studies, only two dealt specifically with the issue of obesity [8] and [24]. In another systematic study, [14] focus on the usage of healthcare via cell phones: twenty five studies were analyzed leading to an overall positive conclusion on the efficacy of wireless mobile technologies to generate improvements both on the clinical and process levels. In this review, four studies were cited in the area of obesity management and focused on improving physical activity [1, 9] and interventions for obesity [15, 23]. It appears that although telemedicine is used extensively in healthcare, only a few studies were applicable to weight management.

One other perspective that is often not addressed in the studies is the cost-effectiveness of the interventions. [2] indicate how in the US, an increase in weight is correlated to an increase of medical cost (18% to 91% for BMI 30 to over 40 relative to normal weight <25). An earlier study by [3], discusses cost-effectiveness of some medical interventions in the UK. Although these results should be viewed with caution due to the limitations of the studies, it is suggested that diet and exercise plans costs are comparable to those of medical treatments. However, a recent study by [12] proves that the weight watchers programs are not cost effective as it involves travel time. Joo explored whether a remote-type program would result in a more cost-effective solution for healthcare providers than a visiting-type only obesity management program. Although contextualized to Korea, this study suggests a higher cost-effectiveness of the former. Our research design will include a similar study.

Table 1 summarizes relevant research results where mobile technology was used in obesity or overweight interventions. It is noticeable that most applications of technology were small in scope. Some restricted to push of data where patients used mobile phones to send data to their mentors. Others, such as the recent study by (Lee et al., 2010) are more sophisticated. Lee's solution offers a personalized diet plan, a calories calculator and a diet game. However, research methods were not rigorous and the sample size very small for any conclusive research. Kornman's solution [16] offers e-contact to teenagers participating in the study and concentrates on motivational messages. Joo's solution [12] also sends messages to participants for a similar aim. Both studies do not relate sufficient data analysis for an interpretation of results.

Table 1. Mobile technology for obesity or overweight interventions

Clinical evaluation process	Outcome measures and Results
Goulis et al 2004 [8]: To determine if monitoring blood pressure, weight and life style through telemedicine has a clinical, metabolic and quality of life impact in overweight and obese patients.	
RCT, n(i) = 45 & n(c) = 77; Age>18 and <70; BMI > 25 kg/m^2; 6 months study. All participants were enrolled in an obesity treatment program consisting of diet (caloric deficit of 500-600kcal/day) and physical activity (exercise 20-30 min, 5 days at week) guidelines. In addition, participants in the intervention arm measured and transmitted their blood pressure, weight and answered 2 questions: "did you follow your diet plan during the last 2 days?" and "did you follow your exercise plan during the last 2 days? Patients sent data 3 times at week for 6 months to an automated call center through a regular phone.	The following was used to measure the outcomes: Body weight, BMI, Blood pressure, laboratory parameters, Health-Related Quality of Life, visual analog scale of European Quality of Life, Obesity Assessment Survey and a satisfaction questionnaire. At the end of the intervention, there was a significant difference (P=0.05) between the weight of the patients in the intervention group (89.2kg±14.7kg) compared with the control group (99.6kg±23.8kg). BMI was also lower but not statistical significant (intervention group 33.7±5.2 and control group 37.2±8.7; P=0.06). A significant difference in total cholesterol (220.7mg/dl ± 42.6 mg/dl and 239.6mg/dl ± 41.5mg/dl; P=0.01) was noticed. There was no difference in the quality of life parameters among the groups
Mattila et al., 2010 [18]: To investigate the validity of self-observations, behavioral changes and weight patterns for weight management.	
30 volunteers enrolled; Age 29 (range 25 to 54); BMI 28.8 kg/m^2 (range 24.7 to 32.1); 12 weeks study. Volunteers were provided with a mobile phone diary tool for recording and displaying self-observations. They were asked to record (as essential) daily weight and steps, exercise duration and type (distance, intensity and average heart rate as optional) and meal type: light snack, heavy snack, light meal or heavy meal (number of drinks and energy in kcal optional). They were asked to send the data once a week by email or multimedia message.	Authors concluded that the validity of self-observed weight tend to be underestimated. Authors reported that decrease in heavy meals and increase in light snack correlates positively with weight lost. There were no significant differences between weight-losers and non-losers, but weight-losers tended to decrease their proportion of heavy meals more. Other observations: weight increase during weekends and decrease during weekdays.

Table 1. (*Continued*)

Lee et al., 2010 [16]: To evaluate a mobile phone-based weight control system	
Case control study: n(i)= 19, n(c)= 17; Volunteer subjects; 6 weeks study The mobile application contained 2 modules: a diet planner and a diet game. The planner provided personalized diet information and calculated calories and exercise level. The game was designed as a learning tool.	The following was used to measure the outcomes: Fat mass, Weight and BMI. We found that this study does not have a rigorous methodology. It is difficult to conclude from the data presented in tables whether the system was effective or not.
Kornman et al. 2010 [16]: To examine users' participation in a telemedicine intervention for overweight management	
55 patients between 13 and 16 yrs old received a community based intervention for overweight and obese adolescents with additional e-contact by email and short message service (SMS) communication. The purpose of the e-contact was reinforcing key healthy lifestyle principles by delivering messages from seven categories: e-contact commencement, health eating, being active, goal setting booster session reinforcement, self-esteem/stress management, and holiday messages. Messages were sent on monthly basis initiated and followed by a facilitator. Engagement was defined by the number of replies received by patients.	Authors' used a satisfaction questionnaire to measure the outcomes of the study. 53 % of replies were sent via email and 47% were sent by SMS. Engagement was modest and predictors of reply rate were not identified.
Wu et al., 2010 [26]: To examine users' participation in a telemedicine intervention for overweight management in type 2 diabetes	
61 patients were invited to a study, 15 refused participation, 46 were randomized into the intervention group (n=25) or control (n=21) group. Patients were eligible if at least 18 years old, had a confirmed diagnosis of Type 2 diabetes, body mass index (BMI) > 28 kg/m^2, English speaking with access to telephone. Weekly telephone calls which repeated the key messages given by clinicians were delivered to the intervention group over 12 weeks. A semi-structured interview followed up.	Authors' used a weight loss target to measure the outcomes of the study. The paper does not provide weight loss figures and rather discusses how patients perceived the usefulness of the messaging. General impressions and feelings were collected, frequency of telephone calls commented upon and usefulness of telephone calls. It is unclear from the study if there is effectively a correlation between text messaging and weight loss. More over, the study was restricted to mainly white British participants.
Joo et al., 2009 [12]: To study cost-effectiveness of a remote type program (internet website and mobile phones with a short message service) in achieving bodyweight reduction	
925 patients were split into 515 receiving a visiting-type program by a public health centre, and 410 received a remote-type program. Patients were recruited by notices on local television channels and inclusion criteria were BMI >= 25 kg/m2 age 20-64 years, overweight subjects with central obesity. The intervention group received 2 weekly sms prompts for behavior modification and accessed diet plan on a website.	Authors' used a weight loss target of 5% over 12 weeks to measure the outcomes of the study. The paper does not provide weight loss figures and patients' acceptance of the technology, but rather focused on a study of cost-effectiveness.

To conclude this section, in all the studies where mobile applications were used, three major areas of concern can be reported: the penetration rates of mobile phones in the various context of studies, the acceptance of mobile phone usage for healthcare and the sample size and methods of the conducted studies. These three areas will be included in the design of our solution.

5 Preliminary Data in the Context of Qatar

To explore the three dimensions of our study, namely, **(R1)** design and implementation **(R2)** technology acceptance and **(R3)** cost effectiveness, we conducted interviews and a focus group. In the first phase, one to one interviews were arranged with health practitioners (five physicians with several years of experience working in Qatar and three dieticians) to test and frame the idea and the local challenges. A focus group was then conducted with fifteen physicians from the main hospital in the country, introducing the idea of this project and gathering feedback on contextualization of the project to the Qatari population. We hereby detail the outcomes of this study.

One to one interviews with physicians: the five physicians were interviewed in October 2010 for their experience of practicing medicine in Qatar for a few years and for being in daily contact with patients at the hospital. Some of the interesting points raised relate to attitudes towards health (or lack of) from patients in Qatar. Some cultural beliefs ("it is all in gods' hands") make some patients not keen to take actions when faced with a serious health issue. Food, and sharing food is also perceived as a social activity and avoiding food is tricky. Some challenges in using technology were also discussed, such as the problem of languages barriers and the lack of willingness to use ICT (Information and Communication Technologies) by the elderly and less educated members of the society.

One to one interviews with dieticians (October 2010): We met wit three dieticians; one is a practitioner at the main hospital in Qatar and meets daily with patients who were referred by their physicians to loose weight. This dietician deals specifically with overweight diabetic patients. The purpose of the interview was to explore the methods used by the obesity clinic at the hospital. It turned out that the clinic is not yet operational but is expected to open soon.

Moreover some of the major issues dieticians deal with relate to low health education as well as low Information Communication and Technology (ICT) education. Both concepts relate to the extent to which patients are self-aware of basics of general health and are capable of finding the information. For example, notions of calories, food composition and portions are not usually obvious to these patients. Dieticians use three established diets at three levels of calories and meet with the patients to discuss the food pyramid and portions. Visuals and 3D shapes are used for portion control.

The other two dieticians work at local universities and shared their thoughts on this subject. They deal mainly with young adults and observed that many gain weight as they join the university and have difficulty keeping a balanced diet and maintaining exercise. The heat, the absence of real sports programs (especially for girls) contribute to the problem. Both dieticians have expressed interest in this study and will be willing to participate and help design experiments.

Focus group (November 2010): the session started with a short presentation of the proposed technology, how it will be applied for obesity management and the methods of conducting the research. Participants then responded with their comments and highlighted some of the potential challenges to the study.

The outcome of all these interviews highlighted the potential interest in such a study. The provision of motivational support and social networking through mobile technology was perceived as very promising and worth exploring. This is more so as physicians pointed out lack of motivation as being a major difficulty with the patients they see regularly through the local hospital. Some concerns were voiced over the learning curve patients will need to go through to adopt and use the technology. It is felt that even in the scenario of voice messages only, patients and especially the elderly would need some initial training. As a result, it was suggested to pilot the study on a group that would not require such training to first make sure the technology is developed properly. Moreover, it was noted that technology in isolation will not function and must be accompanied by an obesity management program. It was also suggested to include access to an operator through the proposed solution and the ideal operator being a dietician. There were questions around the diet and calories intake calculations. Patients need to first be briefed about ways to communicate portions over a voice or text message. There seems to be a broad agreement that diet plans are not well understood by the population of patients that visit the hospital. The educational component is essential for the success of this project. Offering the service is more than just English was suggested. Patients speak Arabic of course but also some other languages within the expatriate community.

Our interviews and focus groups lead us to consider in our research design several key ideas like adjusting the trials to fit a highly health literate and technology aware population, concentrating on the motivational and social part of obesity management when designing the technology, designing culturally adapted stealth interventions that also adapt to the climate and to the social-religious norms, including a strong educational health and diet component to the application and considering the translation of the service into more than just English.

6 Conclusions

Our preliminary research highlighted that successful OMPs have to be based on four dimensions; a multi-approach to weight loss, behavioral changes, social support, and inclusion of a longer term plan to maintain weight loss. The local interviews and focus groups further revealed that within these dimensions, special attention should be given to motivation, to local culture and climate, rigor that educates users on health and diet habits. In this paper, we focus on the technology design.

Mobile technology has penetrated all regions, all cultures and all demographics. The penetration rates of mobile phones may still be a hurdle in some countries, facts suggest it is not so in Qatar. Indeed, excluding the transient labor population, Internet penetration among Qatar's residents is 63 percent, 54 percent are computer users, and 120.8 percent are mobile subscribers [11]. Mobile phones subscription rate in Qatar is high and reaches 120.8%. We will use mobile phones and web to integrate members of our OMP social network to push (and pull) and sustain weight control efforts through education, stealth intervention, clinical check points and group dynamics. The technology will come as one dimension of a multi-approach to weight loss, as an enabler to behavioral modifications and as one of the means for social contact and support. From the users view, the technology will allow access to a mobile application through which data can be entered and information received. Users will be able to periodically enter current values of predetermined parameters, (e.g. weight, physical activity and food intake). The input parameters are then added to the users' profile and accessible through a mobile application or on a website (both options will be provided to adapt to various users' needs). A mobile application has the advantage of readiness and availability, but may discourage users from a cost or readability perspectives). An online website requires the voluntary act of visiting a site but also may be viewed on a large, colored screen and can offer additional possibilities. Based on the participants' input, the system will respond with automated as well as personalized content through text and/or voice messages. To the extent this is possible; we will personalize goal-specific prompts tailored to patient's age, gender and preferred language (English and Arabic). The frequency of the messages will be determined through our research. The messages will address motivation (automated text and voice messages that fit the participants' original profile and other specific interventions as a follow-up to what clinicians observe), education (in the form of FAQs, a forum for Q&A, a section on health tips and advisories, a section on inspiring stories (personal accounts) and periodic quizzes through which participants can test their understanding of the obesity management program), reminders about appointments with physicians or dieticians and, social support (there will be a possibility to access a restricted social network of registered users). From the mentors' view, the technology will allow access to an online application (web-based) where users' entry is available in an aggregated format. They can access the users' obesity management program's plan and view historic use of the system. The system will allow customization of some voice or text messages if there is a need for an intervention.

Our proposed solution for obesity management leverages mobile and web technology to link different players in the health ecosystem and integrate them for the desired results in a cost effective manner. In the future, we plan to address three major areas of concern that surfaced around mobile phones in previous studies: penetration rates of mobile phones, acceptance of mobile phone usage for healthcare and sample size of the conducted studies.

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A Web and Smart Phone System for Tibia Open Fractures

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Abstract. This paper presents an integrated System for Tibia Open Fractures (STOF), based on web and mobile phone applications. A rapid prototyping method was followed based on Adobe Fireworks CS3. The database is developed in SQL Server 2008. The application is created in Microsoft Visual Studio 2010 Ultimate, using ASP.NET programming language. A system that includes an online database and a smart phone application for recording, monitoring and studying patients with tibia open fractures is developed. STOF is designed to be doctors-friendly using classifications and knowledge grouping specialized for tibia open fractures.

Keywords: Tibia open fracture, web database, smart phone, mobile.

1 Introduction

Tibia open fractures usually are associated with severe bone and soft-tissue injury. Infection of the fracture site and necrosis of the soft-tissue envelope greatly increase the risk of inflammation, nonunion and trauma complications. Gustillo and Anderson's classification of these injuries is useful in guiding treatment and predicting outcomes. Antibiotics prophylaxis starts as soon as possible after the injury in order to minimize the risk of infection [1].

The treatment of tibia open fractures continues to be a challenging problem. The basic principles of treatment for open fractures have changed little over the past decade. However, the methods used to achieve the goals of treatment have evolved. Recent advances in the treatment of open fractures focus on the treatment of open fractures of the tibial shaft [2].

Definite treatment of the tibia open fractures remains challenging. Advances in biology implants, plastic surgery and fracture stabilization, such as locked intramedullary nailing, have led to improved prognosis for functional recovery and limb salvage. Despite improved union and limb salvage rates, the prognosis for severe type III tibia open fractures remains guarded and outcomes are often determined by patient psychosocial variables [3].

A systematic review to derive evidence-based recommendations concerning primary amputation versus limb salvage for type IIIB and IIIC open tibia fractures

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was conducted in [4]. The question of whether to recommend amputation or salvage after type IIIB and IIIC tibia fractures remains unanswered.

Apart from medical doctors issues, parameters of nursing care extend to pain relief and positioning, nerve and vascular assessments, safe mobility, self-care, and prevention of complications towards a continuum care [5].

Therefore, a variety of issues still remain unclear requiring a closer, systematic and more detailed medical data collection for further research. The amount of information required or worthy to be used for medical research issues has grown and as a result, essential elements are often not recorded and lost.

Smart phones have been employed widely in health care practice. The level of their use is expected to increase, especially if they are loaded with doctor suitable functions and software applications. The lack of such applications is noticed even in countries with leadership role in mobile technologies, as it is mentioned in [6].

The impact of mobile handheld technology on hospital physicians' work practices and patient care is systematically reviewed in [7], where the authors recommend on future research about the impact of the mobility devices on work practices and outcomes.

This paper presents an integrated system based on web and mobile applications, for recording, monitoring and studying patients with open tibia fractures. The system can be accessed through any electronic device with an internet connection and a web browser. Our goal was to create a system that contains most of the scientifically validated data elements, reducing this way omission and improving consistency, by standardising the reporting language among medical doctors. One of the benefits of the system lays in its updated database that contains all of the scientifically validated medical elements that can be easily extracted and exploited for research issues, using standard SQL commands. In addition, the system's web and mobile interfaces are designed to require almost no text entry and editing and is based on the traditional medical way of acting, (starting from History to Physical Examination, then to Laboratory Tests and Imaging Examinations, etc.), thus making it a doctor friendly system. Therefore, the system requires almost no training and helps doctors to work easier and in a faster way.

The remainder of the paper is organized as follows. In Section 2, we introduce the methods used for software quality assurance and the technologies used for the development of the system. Section 3 describes the system's web and mobile phone applications. Finally, discussion and future work are described in Section 4.

2 Methods

The life cycle of a software system is described with a variety of models. The Classical model is separated into four basic phases; the *requirement analysis* phase, the *development* phase, the *testing* phase and the *maintenance*, as it is shown in Fig. 1.

In addition, there are different methods for quality assurance in software production such as the Rapid Prototyping method, the Spiral model method, etc. [7]. In this paper, a combination of the aforementioned methods was used for the *requirements analysis* phase and the *development* phase of the Classical model.

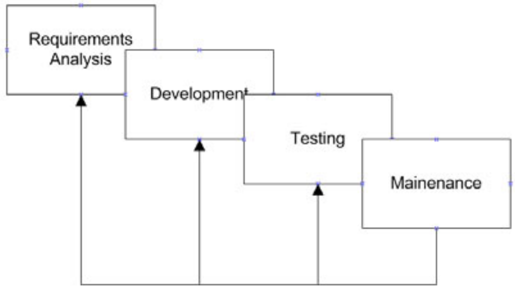

Fig. 1. Classical model's basic phases of a software system

This way, a software engineers' team and a medical experts' team consisted of Orthopaedics and Emergency Department General Practitioners was designated. The two teams arranged a series of meetings using Adobe Fireworks CS3 for the creation of rapid prototypes. When the requirement analysis reached an acceptable level and was translated to a rapid prototype that fulfilled the medical experts' team requirements, the software engineers' team proceeded through the development of the system.

The general architecture of the integrated system regarding its components interconnection is shown in Fig. 2.

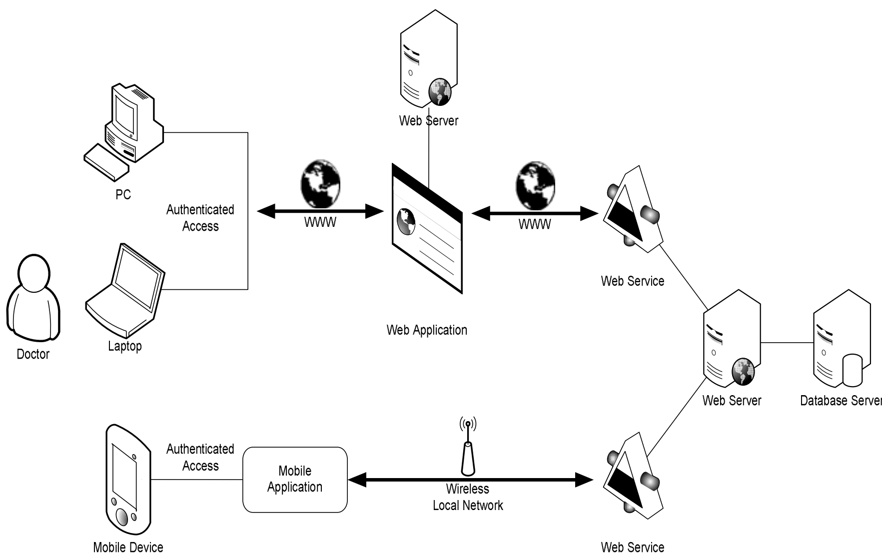

Fig. 2. The Architecture of the Integrated System: Components Interconnection

The system implements a client - server architecture. Doctors and authorised personnel have access to the integrated system through client applications, a web application and an application for smart phones and mobile devices, with friendly and easy to use interfaces. In order to achieve platform independence, the client applications communicate and exchange data with the database through web services, which allow data interchange through heterogeneous systems. The web services provide functionality with which specific information can be accessed by client applications after authenticated access.

The integrated system's components are developed in Microsoft Visual Studio 2010 Ultimate, using C# programming language. The web services implementation follows the Windows Communication Foundation (WCF) framework that provides a unified programming model for rapidly building service-oriented applications. The mobile application is developed using Windows Phone 7 Developer Tools. The system's database is developed in SQL Server 2008.

The *testing* phase was based on an exhaustive test case method that resulted into a number of test cases that were followed verifying and validating this way the requirements satisfaction of the software system. The verification and validation of the system were decided by the software engineer's team, the medical expert's team and a third mixed specialty's team from so far uninvolved to the project partners.

The *maintenance* phase lasts from the first release of the system until the software is completely replaced or not used anymore. Two Hellenic General Hospitals have been chosen for pilot installing, "Karamandaneio" Children's Hospital of Western Hellas that places a Children Orthopaedics Clinic covering an area of 1.200.000 inhabitants, roughly the 12% of the total population of Hellas and "St. Andrew's" General Hospital of Patras.

3 Results

We developed a web based and smart phone System for Tibia Open Fractures (STOF). All users that wish to access the web application need to register for a user account via an online application and only password protected access is allowed. After a member user is logged into the system, s/he is able either to search for an already recorded patient or to record a new one.

Following the medical experts way of thinking and acting, the left side main menu consists of Demographic data, History, Physical examination, Laboratory tests, Imaging examination, Surgical operation, Diagnoses, Antibiotic treatment and Complications, as it is shown in Fig. 3.

Fig. 3. Web application basic menu

Suggestively the forms of History, Physical examination, Laboratory tests, Imaging examination and Complications are presented for both web and smart phone applications.

The History form contains data concerning the vital signs of the patient (Blood Pressure, Pulses, Breaths and Temperature), the Weight and Height, the habits (Smoking and Alcohol), the Individual History (G6PD deficiency, HIV, HBV and HCV), the surgical Operations, the Pharmaceutical treatment, the Allergies, the Blood type, the Injury mechanism, the A.O Classification (chosen from a drop-down list) and the Injury force. The same data can be recorded through the smart phone application, as it is shown in Fig. 4 and Fig. 9.

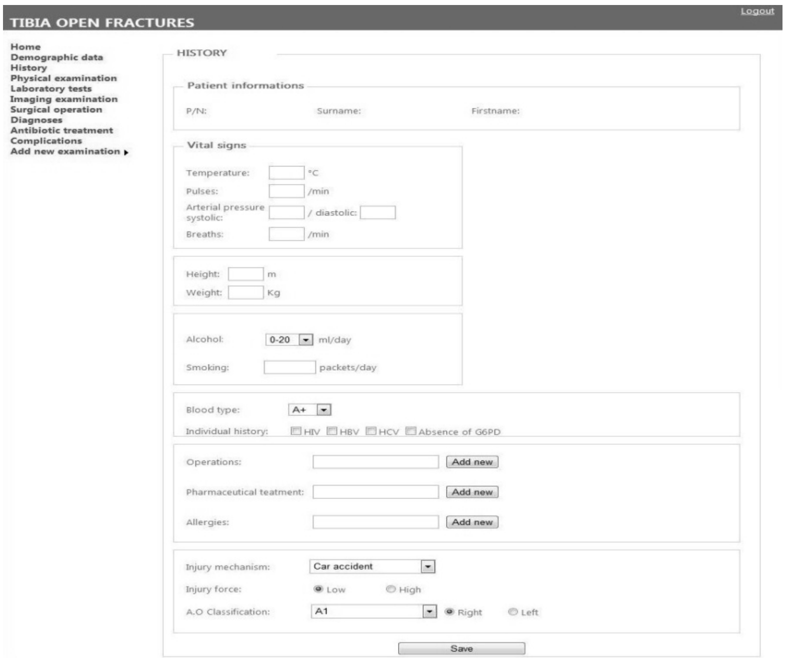

Fig. 4. Web application History form

The Physical examination form contains Gustillo's classification and a set of specialised data for tibia open fractures, such as Soft tissue destruction, Crush, Infection possibility, Vascular damage, Multiple fractures, Head injury, Chest injury with pulmonary damage and Neurological damage, as it is shown in Fig. 5 and Fig. 9.

Subsequently, the Laboratory tests form contains a Blood general examination, a Blood biochemical examination and a Blood culture/antibiotic susceptible, as it is shown in Fig. 6. The smart phone application is designed only to view Laboratory tests and Imaging examinations and not to import data in the data base as it is illustrated in Fig. 10.

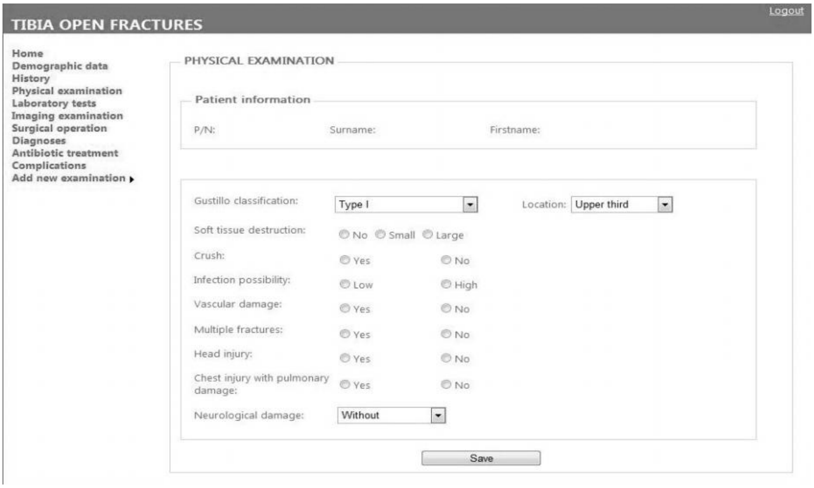

Fig. 5. Web application Physical Examination form

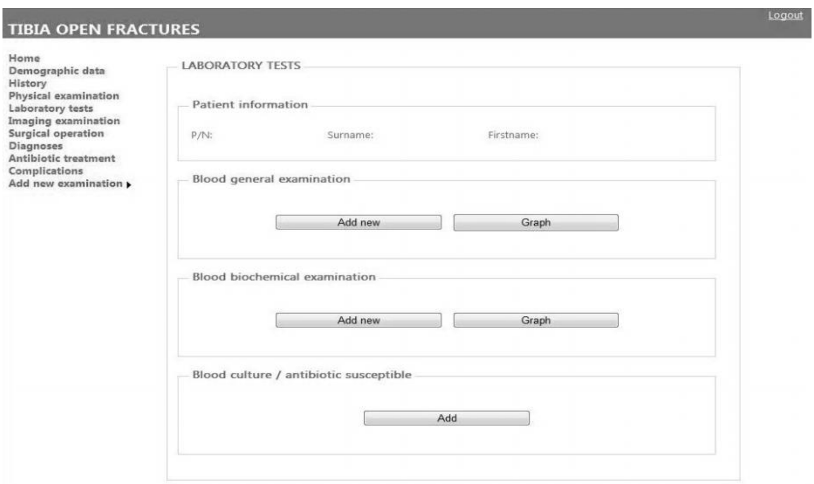

Fig. 6. Web application Laboratory Tests form

The Imaging examination form is composed on uploading X-Ray images, Report documents and checking Findings on the X-Ray, as it is shown in Fig. 7. The Findings are proposed from medical experts on the field of tibia open fractures.

Based on medical experts' knowledge, the Complications form is separated on early and late complications. Scientifically validated data elements are listed in check boxes for the two categories, as it is shown in Fig. 8 and Fig. 10.

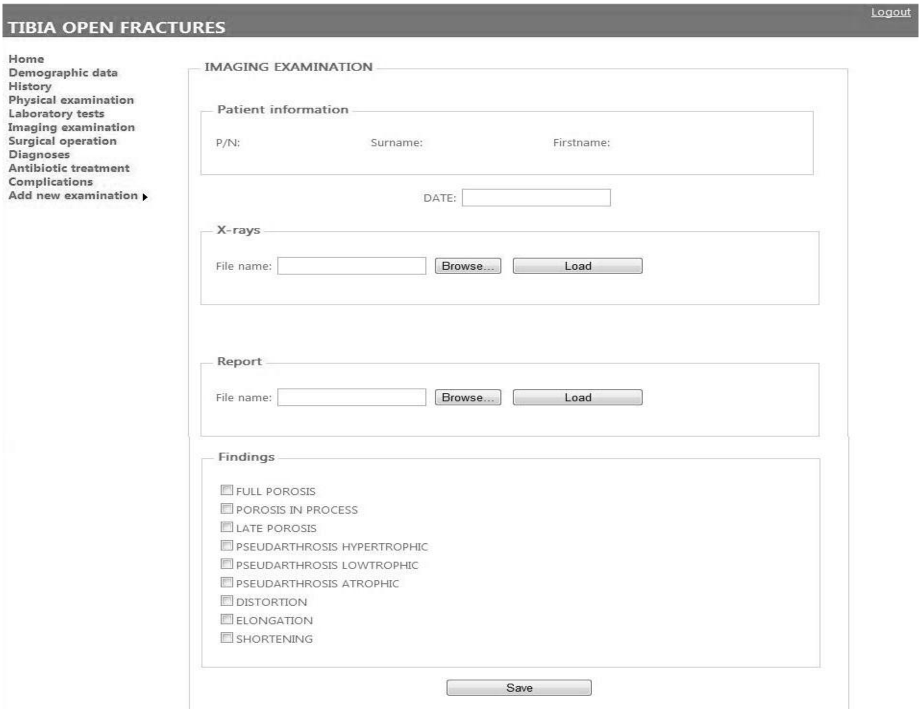

Fig. 7. Web application Imaging Examination form

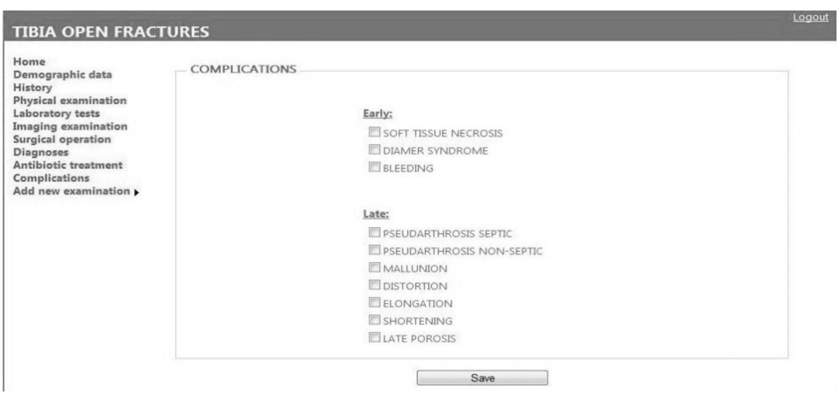

Fig. 8. Web application Complications form

Fig. 9. Smart phone application History & Physical Examination forms

Fig. 10. Smart phone application Imaging Examination & Complications forms

4 Discussion – Future Work

An integrated System for Tibia Open Fractures (STOF), based on web and mobile phone applications, is developed that has several advantages over general software systems for Orthopedic patients. The architecture of the system and the philosophy of the development, follow three major principles. The first principle is: “to follow the way Medical Doctors think and work”. The second principle is: “to make Medical Doctors work easier and faster”. The third principle is: “to record scientifically validated medical data elements for research”.

Concerning the first principle, the left side menu is recognisable from any Medical Doctor “at a glance”, meaning that any Medical Doctor understands the contents of the left side menu labels without any training needs. In addition, the labels’ order follows the way a Medical Doctor approaches a clinical problem, as it is shown in Fig. 3.

Concerning the second principle, “to make Medical Doctors work easier and faster” it is clear now that no special training is needed for a Medical Doctor to be able to use STOF and due to the web application it can be easily accessed. But the major advantage of STOF is that incorporates medical experts’ knowledge on the field of open fractures of the tibia, in the form of using categorisations; translated to lists, radio buttons and check boxes, making the Medical Doctor to work faster than if he had to write down on a paper or to text.

Concerning the third principle, “to record scientifically validated data elements for research” is approached through the categorizations given from the medical experts’ on the field and the incorporation of all these medical elements in the appropriate software forms. This way the user is urged and guided to search and to complete as many scientifically validated medical data elements as possible. This simple mechanism of collecting so many crucial data in a database management system, offers the capability of searching, correlating and resulting on combinations of medical data, in a simple and fast way that so far seemed an extremely arduous task that could not proceed, at least in the medical element detail that STOF offers.

Future work contains an extra interface form for automated medical statistical analyses and a graphical interface with all the medical data elements able to be combined, as an extremely easy mechanism for running queries on the data base.

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LIFEisGAME: A Facial Character Animation System to Help Recognize Facial Expressions

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Abstract. This article presents the LIFEisGAME project, a serious game that will help children with ASDs to recognize and express emotions through facial expressions. The game design tackles one of the main experiential learning cycle of emotion recognition: recognize and mimic (game mode: build a face). We describe the technology behind the game, which focus on a character animation pipeline and a sketching algorithm. We detailed the facial expression analyzer that is used to calculate the score in the game. We also present a study that analyzes what type of characters children prefer when playing a game. Last, we present a pilot study we have performed with kids with ASD.

Keywords: autism spectrum disorder, emotions, serious games, facial animation, emotion recognition, HCI, consumer health informatics.

1 Introduction

Understanding emotions is a key element in social interaction because it enables individuals to accurately recognize intentions of others and promotes appropriate responses [1]. But what comes naturally for some, others struggle to achieve it, like how a person with ASD (Autism Spectrum Disorders) can recognize emotions. Impairments in social interactions in ASD are frequently observed as a limited use of nonverbal behaviors, including eye gaze, facial expressions, and a lack of social and emotional reciprocity [1].

Individuals with ASD are also less likely to attend to faces [2] and are impaired in face discrimination tasks when compare with typically developed children [3-5]. Most recently, technology has been playing a more active part in promoting facial recognition and helping individuals with ASD to understand emotions. Some examples come from games as "Mind reading" [6] or the animation series "Transporters DVD" (www.transporters.com). However, these tools do not explore the maximum potential of interactive applications.

Some authors believe that individuals with autism "may not learn to recognize emotional expressions in real time during live social situations, because emotions are

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fleeting and do not repeat in an exact fashion, which may reduce the number of opportunities to systematically learn from repetition" [7]. For Ambadar, Schooler and Cohn [8] dynamic emotion displays facilitate recognition, particularly for more subtle facial expressions.

Computer training and multi-technology have been shown to be successful for teaching emotional skills to children with autism [7, 9, 10]. Accurate recognition and interpretation of facial expressions help individuals decide when to make socially acceptable statements and provide guidance in determining approach or withdrawal strategies in interpersonal transactions [1]. But when creating a computer game to help children with ASD to understand the world of emotions we need to build it in such a way that is motivating and takes into account the particularities of this disorder.

LIFEisGAME attempts to apply a serious game approach to teach children with ASDs to recognize facial emotions using real-time automatic facial expression analysis and virtual character synthesis. Most of the current means of teaching children emotions are non-interactive, and the effectiveness of these existing games in the pedagogical way is questionable. Meanwhile, most existing training programs have not systematically focused on teaching emotion recognition, but instead were incorporated as part of social-skills interventions group [11]. In order to achieve better learning outcomes, we designed an interactive game to engage the children and help them learn emotions in a fun way. We use faces of characters, faces of the participant and faces of people the participant is familiar with to help them engage with the learning process. In this article, we will outline an overarching view of two modes of the game we developed, including the pedagogical modes in the game, the technologies that enable the game, and some preliminary user testing results. Future research and development concerning the game will be discussed at the end of this article.

2 Game Design Overview

Based on the learning cycle defined in [19], we have outlined in LIFEisGAME four different pedagogical modes: The first mode is "Recognize the expression", where the player is encouraged to identify a pre-selected expression in an avatar showing emotions in a random order; "Build a Face" is the second mode, here the player needs to build a certain expression on a 3D avatar; In the third mode "Become your avatar" the player uses its own facial expression to control the avatar expressions; finally, in "Live the Story" the player is presented with a story and must perform the correct facial expression in certain moments of the plot.

In this study, we developed a game prototype based on "Build a Face". It includes two game versions and runs on a touch-screen computer. The game starts with a list of avatars that the user can choose from. This avatar becomes the character, the player will use during the game. The first version we call "free-play mode" in which the player controlled the expressions of a 3D avatar by drawing on a sketching canvas on the right side of the screen. After the player draws an expression, the player can drag the avatar to a timeline on the bottom of the screen. After drawing several expression the player can press the "Play" button, then the expressions are interpolated and an animation is automatically generated (see Fig. 1a).

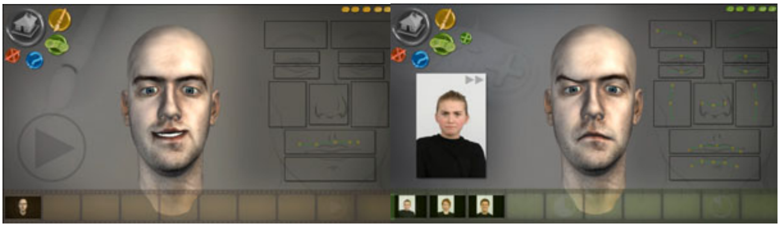

Fig. 1. Build a Face. Left: Free-play mode, Right: Matching the expression of the photography by sketching on the canvas

In the second version of this prototype, and after choosing the avatar, the player must choose some photos with facial expressions from the game database or take a photo of itself with the webcam. The player can choose up to a maximum of five photos to play with. After choosing the expressions to play with, the player can start the game. The objective is to bring the avatar's expression, by sketching, as close to the expressions in the images. On the bottom of the screen, there is a timeline with all the expressions the user will play with and a time bar that indicates how much time the player has left (see Fig. 1b). The score is calculated by the similarity between the avatar sketch and the photo expressions, the number of movements required and the remaining time. For more information on the learning cycle and the pedagogical game modes implemented in LIFEisGAME, please refer to our previous work in [20].

3 Technologies Enabling the Game

To achieve the game modes depicted above, we need some supporting technologies. The main technological impact of this is the real-time virtual character synthesis pipeline and the real-time facial expression analysis algorithm.

3.1 Real-Time Virtual Character Synthesis

Each face is unique, causing the primary difficulty in animation. LIFEisGAME aims to create a virtual representation of the player's face and map his or her facial movements and behaviors onto a virtual face. Achieving this goal requires facial synthesis in real-time with cinematographic quality images, which we have the additional challenge of capturing during routine play—i.e. not in a laboratory setting where players could wear markers. At the same time, the game must support different styles of characters varying in shape and appearance. The key technology behind the facial animation system will be the definition and deployment of a sophisticated rigging pipeline and a motion capture technique. Rigging is the process of taking a static, inanimate computer model and transforming it into a character that an artist can manipulate to create animations [13]. Thus, an automatic rigging process becomes crucial to allow the animation of 3D avatars that are created on the fly (e.g. avatars representing a specific person) and to guarantee results with cinematographic quality.

In LIFEisGAME, we study the creation of a new automatic animation pipeline. The research provides a significant advance over traditional games' passive approach. In LIFEisGAME, dynamic avatars embodied from the players themselves can participate in game interactions and scenarios.

3.2 Real-Time Facial Expression Analysis

In order to perform the facial expression analysis for the current game prototype, we used the solution presented on [18]. The goal is to recognize and classify a facial expression. The algorithm starts by taking as input photo and enhance the contrast to ease the calculations. Then, after a skin color conversion and segmentation step, the algorithm finds the largest connected region on the image. The original algorithm used a threshold value to determine if a certain pixel color was either skin or not. However, this solution was not sufficiently flexible and would not work for different skin colors or for people with blond hair. This is due to the fact that the difference between skin and hair colors is very small. Therefore, it was necessary to implement an adaptive threshold algorithm to increase the number of cases to detect a face. At this point, the algorithm checks if the image obtained can be a face, i.e. if the proportions and size are sufficient and valid (see Fig. 2). If the image is a face, then the algorithm may proceed. Otherwise, the threshold is lowered until a given minimum and the process is repeated.

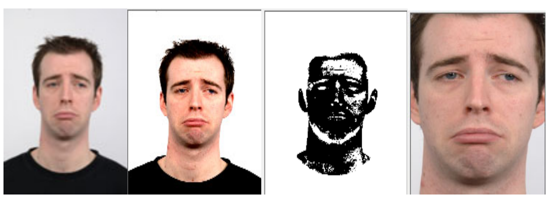

Fig. 2. Face detection algorithm. From left to right: the original input photo; after enhancing contrast; after skin color conversion and segmentation; after finding largest connected region.

If the previous steps were able of finding a possible face in the image, the next stage consists in performing an image binarization. Consequently, the process of detecting the actual face is easier and we can remove the hair, neck, etc. from the image. After this step, the facial components are extracted, namely the eyes and mouth. The algorithm will then obtain the Bézier curves for each of these facial parts along with its parameters. After these calculations, the parameters of the Bézier curves obtain from each facial part are matched individually against a database. If there is a consensus from at least two parts, then it is possible to recognize an expression. For example, if the result for the left eye is "Sad", for the right eye is "Disgust" and for the mouth is "Sad", the final result for the person in the image is probably sad.

4 User Preference Study

Together with the evidence presented above it was also necessary, as a requirement of our game, to create an experiment that would help to better understand children's characters preferences. In this experiment we would assess children´s preferences between a group of characters with different characteristics by showing them examples (images) of such characters and by asking them which one they preferred above all. The different types of characters would be 3D (complex cartoons), 2D (simple cartoons), photorealistic characters, (female, male), children (male, female) or animals and familiar and unfamiliar characters.

Based on this experiment our goals were:

a) To identify appealing characteristics,
b) Identify preferred type of character and
c) Get a hierarchy of preferences.

4.1 Subjects

Our sample was composed by 145 mainstream children with ages varying from six to 12 years old (M=8.34, SD= .995); in a total of 70 males and 75 females. The 145 participants were students of two State Primary Schools and were distributed between the second and the fourth year of school (M=2.85, SD=.739). All participants were Portuguese speakers. This was a convenience sample because protocols of collaboration between the school's participants and the present project were made. All children´s parents were aware of this collaboration and consented the experience.

4.2 Procedure

Trying to answer to the previous mention questions: Do children prefer 3D (complex cartoons), 2D (simple cartoons) or photorealistic characters, do they favour adult (female, male), children (male, female) or animals and is there a difference when talking about familiar and unfamiliar characters? - Through Google search engine a set of images was selected that represented each one of the types of characters available to use in the game. All images selects are identified by their internet link to preserve author privacy.

The characters chosen varied in three types of format:

a) Photorealistic,
b) simple cartoon characters or 2D characters and
c) complex cartoons or 3D characters.

All characters could also be children (both genders), adults (both genders) or animals. An extra variable considered was familiar and unfamiliar characters know to children by the media to evaluate how this would affect their choices.

The best set of representative images was selected by three judges, expertise in facial recognition. A PowerPoint slide show with selected images was presented to the participants collectively in their class groups, or when these groups were too small in more than one class group together. In each slide show, in a total of 17, children could see four characters, each one number from one to four (see Fig. 3). All characters showed the same emotion (happiness) and all were unknown by the media, except when this variable was considered. In each slide just one variable was assessed, for example, preferences between photorealistic and complex/3D cartoons (see Table 1).

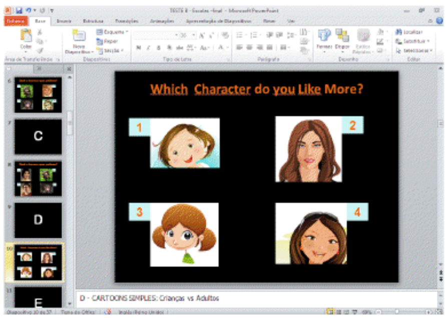

Fig. 3. Example of slideshow (image links: http://www.shutterstock.com)

Gender variable was controlled for each slide and sometimes the same variables were repeated but characters changed from female or male to assess results in both genders. Other aspects like images positioning, part of body exposed and size of image was also taken into consideration to avoid answer contamination. Each child had an answering sheet, were he/she had to mark their answer and other data like age, and school year was also added. All questionnaires were confidential. The Instructions presented on the PowerPoint slideshow were: Which character do you like more?

4.3 Results

The SPSS software, version 18.0 was use for the statistical analysis of the data. For each slide was calculated the valid percentage for each character. For the photorealistic characters, children seem to prefer animals and the same result is found when talking about 2D (simple cartoons), 3D (complex cartoons) or even familiar versus unfamiliar characters. When comparing preferences between 2D and 3D cartoons, children seem to choose 3D characters, except when talking about animals, in this case photorealistic characters are preferred instead of 3D cartoons. In terms most voted characters first we find familiar animals (70.1%), in second 3D unfamiliar animal cartoon (66.2%), in third 2D animal cartoon (62.8%) and lastly photorealistic animal (58.6%) (see Table 1).

Table 1. User Preference Study Results

Slide	Choices	Results (%)
A	Photorealistic characters – Adults Vs. Children	Children (57.9)
B	Photorealistic characters – Animals Vs. Children	**Animals (58.6)**
C	Photorealistic characters - Adults Vs. Animals	Animals (42.1)
D	2D Cartoon – Children Vs. Adults	Adults (60.0)
E	2D Cartoon - Children Vs. Animals	**Animals (62.8)**
F	2D Cartoon - Adults vs. Animals	Animal (37.2)
G	3D Cartoon – Children Vs. Adults (males)	Children (50.3)
H	3D Cartoon – Children Vs. Adults (female)	Adults (35.2)
I	3D Cartoon – Children Vs. Animals	**Animals (66.2)**
J	3D Cartoon – Adults Vs. Animals	Adults (36.6)
K	3D Cartoon Vs. Photorealistic (children)	3D (38.6)
L	3D Cartoon Vs. Photorealistic (adults)	**3D (56.6)**
M	3D Cartoon Vs. Photorealistic (animals)	Photorealistic (46.2)
N	Familiar Vs. Unfamiliar (male/children)	Familiar (55.2)
O	Familiar Vs. Unfamiliar (female/children)	Familiar (56.6)
P	Familiar Vs. Unfamiliar (adults)	Familiar (55.2)
Q	Familiar Vs. Unfamiliar (animals)	**Familiar (70.1)**

5 Game Testing and Validation

A pilot experiment was made with two children, both male and with Asperger's syndrome. However, we have made two sessions with one child and three with other child to test how they behave when playing the game in different occasions. The children were always accompanied by their therapist. In this study, we used the game mode "Build a Face".

These experiments pointed to several important issues. Although the children reacted positively to the game in the first session, one of them was more resilient to play in the second session. However, this could also be due to the fact that this child was submitted to an intensive speech therapy session minutes before our second session of testing which made him become very tired. Also, this second session wasn't preceded by a plan made by the therapist to prepare him for the game tasks that we were presenting. Nevertheless, this result points once again to the necessity of a context in the game and to the possibility of customization.

We also noticed that the children enjoyed the touch-screen interface, but at some times, experienced some problems due to the small size of the curve handles. Since these children were used to the utilization of computers, they quickly changed to the mouse to overcome this difficulty. However, this is clearly a point to take into consideration, since it may be a problem not only for children with high-functioning autism, but mostly for children with a lower functioning level.

6 Conclusions and Future Work

LIFEisGAME aims at providing children with ASDs a fun game that can effectively help them recognize and express emotions through facial expressions. The game approach is important given the fact that games can stimulate competition in the player, who attempts to beat previous scores. The cooperation and competition game techniques allow the player to become more immersed in the game, in contrast to traditional facial emotion recognition applications.

In terms of character preferences, we can observe that there is a sense of hierarchy; children seem to prefer first familiar characters, then 3D, 2D cartoons and lastly photorealistic characters, being animals the most voted in all categories. It is obvious that the media plays an important part in children's preferences. When we look at similar traits between the most voted animal characters, we can observe a Gentile/kind posture, presence of big expressive eyes and that the animals seem to be common to children like dogs, monkeys…

Human characters share some features observed in the animals characters, like the gentile posture and big expressive eyes and when looking at the shape of the faces - we can detect babyface characteristics. In addition, looking at the most voted children character, he has some female features like the long hair and a small nose.

Looking at this analysis, we can confirm some of the findings in Radbound Database [15] like the importance of masculinity/femininity of faces and also the baby face characteristics. Thinking about the game it seems important to have a variety of characters, especially animals, but thinking about the therapeutic purpose of the game in promoting the development of facial recognition and emotions understanding it is important to focus on adults and children characters.

As a limitation to our study, we have the conscience that these results are not obtained in an ASD population, but this the first of several experiments to test the characters likings. Although, being the characters that ASD children are most exposed to are thought for the general population, this experiment is a good starting point. Plus we do not won't to over expose the ASD population that we have available to cooperate with our project. Later on, once the characters are designed character's attractiveness can be tested by ASD children. But one characteristic seems to be coherent and that is the necessity of exaggerate facial expressions, in particular the eyes. Like stated in [16], individuals with autism may need more exaggerated facial gestures to be able to interpret the emotional state of others correctly. As a next step, we are preparing game design document templates to provide to therapists so they can create their own teaching therapy. In the other hand, the prototype testing suggests that the participants favored the game. Nevertheless, the game design needs to take into consideration the individuality of each child, allowing them to customize settings such as characters, color and sounds. The need for customization is echoed by the results of our survey with psychologists, parents, and therapists, who suggested that children would like to create their own avatars and usually have very specific, but changing, interests (e.g. football, dinosaurs).

The user study also suggested that, in addition to human avatars, children want to play with different types of avatars. This result is consistent with our survey with psychologists, parents, and therapists, who suggested that acceptable characters could be humans, animals, or aliens. Furthermore, the animals and aliens should be cartoonish, while the human characters may be either cartoonish or realistic. This is due to the fact that children with ASDs have difficulty recognizing boundaries between the real and the virtual worlds. In future character designs, we will also consider more subtle aspects of the avatars, such as the agreeableness and dominance, which are conveyed through posture and demonstrated through actions. We also hope to take advantage of the face and body of the 3D avatars by giving hints to the player and transmitting information through the expressiveness of the character.

The purpose of the game is to help children with ASDs learn to recognize and understand facial expressions of emotions; therefore, how the game reinforces learning is an important issue to consider. Mechanisms need to be developed in order to avoid behaviors such as making mistakes intentionally to hear certain sounds and simply matching expressions with the pre-selected image. Furthermore, we envision that the game could function as a therapeutic intervention, especially for younger children in the simpler game modes. This could potentially facilitate cooperation between children and their therapists, which would aid in fostering the child's learning. Technologically, to support the development of the more advanced modes outlined in the game mode section, we are developing a novel sketching control system. This system is inspired by the way people draw and would allow a stroke to define the shape of an object, reflecting the user's intentions [17]. Our method will create a real-time simple control system where facial deformation is sketched, which will significantly speed up the creation of facial expressions. This technology will enable patients and therapist to quickly and easily create new facial expressions, without the need of artistic or technical skills. We will perform future user studies to verify the game design enabled by this technology and improve the usability and user-friendliness of its implementations.

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Author Index

Author Index