Dasun Weerasinghe (Ed.)

Electronic Healthcare

International Conference, eHealth 2008
London, UK, September 2008
Revised Selected Papers

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Volume Editor

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Preface

eHealth 2008, the First International Conference on Electronic healthcare for the twenty-first century, was held in City University, London, during September 8–9, 2008. The conference was organized as a meeting point for telecare product vendors, policy makers, government ministers, academics, clinicians and all those involved in electronic and mobile health, to examine and to share ideas contributing to the advancement of electronic healthcare into the twenty-first century.

The conference had a huge success with a large number of paper submissions. Ninety-seven papers were submitted, of which 32 were selected for presentation. Each paper was carefully reviewed blindly by a minimum of three referees from the respective field. A special thanks should go to the Technical Program Committee for their hard and efficient work in the review process.

In addition to the submitted contributions, the conference included a business presentation track with 12 invited talks by key people in the world of eHealth. The business presentation track was chaired by Sir Jonathan Michael (Deputy Director, BT Health).

The success of this conference is to be credited to the contribution of many people. Firstly, I would like to thank the members of the Organizing Committee for their diligence and commitment to the tasks involved. I would like to thank Raj Rajarajan (City University, London) for making the idea of the eHealth 2008 conference a reality with his hard work. Moreover, a special thanks should go to the ICST and Create-NET for technical sponsorship of the event. Last but not least, I would like to thank all the authors who submitted papers, making the conference possible, and the authors of accepted papers for their cooperation.

Dasun Weerasinghe

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Invited Paper

Continuous Monitoring of Children with Suspected Cardiac Arrhythmias*

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Abstract. Advances in wireless communications and networking technologies as well as computer and medical technologies, enable the development of small size, power efficient and more reliable medical multi-parameter recording systems, which can be used for continuous monitoring of patients. Through this paper we present the design and development of an m-health system platform that will be used in order to monitor children with suspected cardiac arrhythmias. The proposed system is based on sensor networks, in order to monitor a subject while being in a predefined area like his/her house; while another module based on PDAs and wearable ECG recorders will be used in order to extent the coverage outside the patient's house. Furthermore the system will be based on a variable sampling rate to conserve power for the possible arrhythmia episode. The system design and development has been completed and currently is going through the initial testing phase for the first improvements.

Keywords: Sensor networks, wireless telemedicine, home monitoring, children arrhythmias.

1 Introduction

Telemedicine has been used for many years in order to improve health care provision or for patient monitoring solutions. Several issues such as the computational capability, size of the devices, power efficiency and cost have been limiting the availability of devices and services to a few special cases [1]. Recent advancements in communications and

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computer systems can help us develop general-purpose systems that are more efficient, much smaller and at lower costs.

In this study, we will focus on the continuous monitoring of children with suspected cardiac arrhythmias. In order to evaluate the size and severity of the problem; arrhythmia is one of the most difficult problems in Cardiology both in terms of diagnosis and management. The problem is particularly pronounced in Pediatric Cardiology because of the variety of etiologies and the difficulty that the children are having in trying to communicate their symptoms. For example in the case of hypertrophic cardiomyopathy, it is known that children are at higher risk for arrhythmias and sudden death than adults. In most of the cases an ECG tracing is required and this is sufficient for an accurate diagnosis, whereas in some cases, a more sophisticated modality is required [2], [3].

As an example a relatively recently recognized rare form of cariomyopathy, the Isolated Noncompaction of the Left Ventricle (NCLV), which is a rare form of cardiomyopathy, poses new challenges. A subset of patients with this disease are especially prone to arrhythmia and sudden death. It is not always possible to estimate the risk of each patient with the available test modalities even if we include genetic testing. Current testing with the holter monitor has proved insufficient because it is limited to 24 or 48 hours of recording during which the patient may be asymptomatic. We care for a group of such children, some of whom are at imminent risk of sudden death [2], [3].

In this study, a mobile health (m-Health) system that will be able to monitor children continuously during their daily life activities is proposed. The system will be able to do real-time acquisition and transmission of ECG signals from the patient, and facilitate an alarm scheme able to identify possible arrhythmias so as to notify the on-call doctor and the relatives of the child that an event or something that denotes malfunction is happening. This system is a significant extension over our earlier telemedicine work in real-time ambulatory monitoring systems [4].

2 Example Cases

In order to better appreciate the problem a brief description of two cases is presented:

Case 1: A few years ago we lost one such child, a four-year-old boy that was our first patient to be diagnosed with this disease. He was presented with a near miss episode of sudden death while at the nursery school and he was revived at the hospital where he was brought unconscious. He was then referred to UK for electrophysiological studies that were essentially normal. He had periods of bradycardia on the holter monitor and during his hospitalization. It was believed that the episode of loss of consciousness may have been related to bradycardia and a pacemaker was implanted. A few months later, while at school, he lost consciousness again and was brought to the hospital but he could not be revived this time. Before dying, an ominous form of arrhythmia (torsades de pointe) was recorded. A few weeks before death, his mother reported a very short episode of near loss of consciousness that retrospectively could have been a short episode of arrhythmia but unfortunately there was no record of it.

Case 2: The second case is that of a nine year old girl with a history of several episodes of loss of consciousness and NCLV. In her case, we were lucky to record one such episode on the holter monitor. She had multiple episodes of supravenrticular tachycardia following one of which there was a prolonged pause that coincided with the witnessed episode of loss of consciousness. She was then started on beta blockers and she remains asymptomatic over the last three years.

The description of these two cases highlights the wide range of clinical presentation and the variety of the underlying arrhythmias that these children present. Some of these children are high risk for sudden death and at the same time it is very difficult to decide for the proper treatment, making their ECG monitoring a very important task. The methods available today for ECG monitoring are clearly insufficient for this purpose. We need a noninvasive or minimally invasive way to record the ECG for extended periods of time and at the same time perform automatic analysis continuously or at frequent intervals.

3 Methodology

In general the design problem has been divided into two cases. For the first case, called "In-house case" the subject is located in his/her house. For the second case, called "Moving patient case" the subject may or may not be located in his/her house. In both cases we require continuous 24-hours monitoring.

In house case: During this case, a sensor network installed in the child's house that will be used in order to continuously monitor ECG signals from the patient [6] – [9]. Several other environmental parameters like light, temperature, sound and acceleration will also

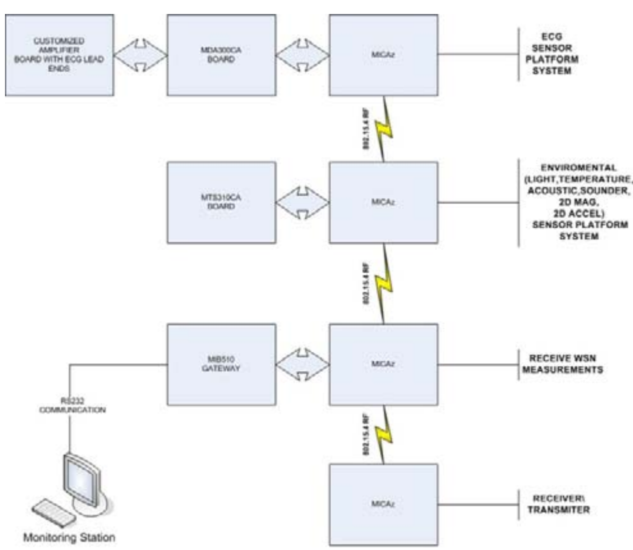

Fig. 1. Block diagram of the in-house wireless sensor network © IEEE 2007 [5]

be monitored so as to continuously check the living conditions. The ECG (3 lead) signal will be recorded by a sensor carried from the child, that will be part of a wireless sensor network (WSN) installed in the house. The ECG sensor has been specially designed & developed by SignalGenerix ltd (http://www.signalgenerix.com) Signal information from the wearable sensor will be propagated to a local monitoring station which will also act as a gateway to the rest of the monitoring network. This case can be described as follows (see also Fig. 1):

a. The cardiac pulse is propagated through the WSN to the local monitoring station with an embedded broadcast algorithm.
b. The local monitoring station is required to collect all environmental measurements (e.g.temperature, 2D accelerometer, sound, light):
   - Sample the ECG signal.
   - Store the sensor data locally.
   - Analyze the ECG signal in order to detect possible cardiac arrhythmias.
c. In the case of a detected arrhythmia:
   - Send an alarm message to the central monitoring station (located in hospital).
   - Send an alarm via an SMS to the supervising doctor and a relative.
d. The central monitoring station is required to:
   - Store data sent from the local monitoring station.
   - Display data transmitted from the local monitoring stations and through a web interface.
   - Analyze the ECG signal further. (send a message (SMS, e-mail etc.) to the doctor).

Moving Patient Case: The second case is more general and will be used in order to complete the coverage of the system. For this case, the child will be monitored using the same ECG recording device but the signals will be transmitted, through a PDA device, directly to the central monitoring system. The transmission will be performed through the use of 2.5G and 3G mobile communication networks (GPRS/UMTS) [1]; depending on the equipment and network.

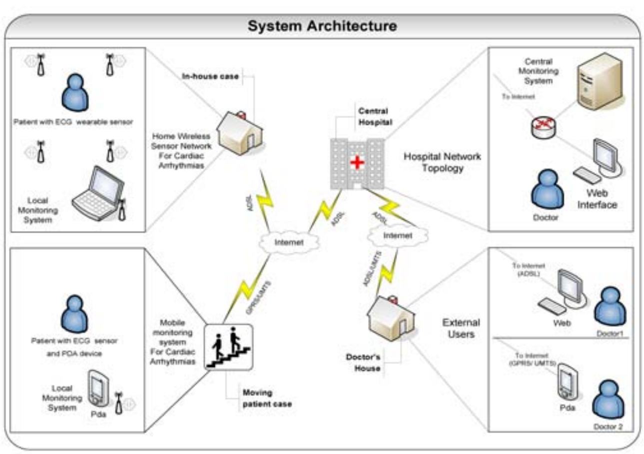

Fig. 2. Overall system Architecture © IEEE 2007 [5]

The information will be stored locally on the PDA and a basic analysis of the signals will be performed locally on the mobile unit (depending on the equipment specification). The central station is required to provide for the storage and analysis and display of information, as well as the notification of the on-call doctor and the relative in case of an alarm. The case can be described as shown in Fig. 2:

a. The cardiac pulse is propagated through the ECG sensors to a PDA carried by the patient. The PDA system is required to:
   - Sample the ECG signal and send it via GPRS/UMTS to the remote monitoring station.

b. The remote monitoring system is required to:
   - Store data for the specific patient.
   - Analyze the ECG signal in order to detect possible cardiac arrhythmias.
   - Send an alarm via an SMS or e-mail to the supervising doctor and a relative.
   - Display data locally and through the web.

Variable rate ECG signal recording: The continuous-time monitoring is limited by the available battery power. In order to achieve better results and more time of transmission we propose the use of a variable-rate signal processing system that will be used to reduce the power requirements by reducing the sampling rate during normal operation, while saving the high sampling-rate and transmission during a possible arrhythmia session. To recognize the power savings, we note that power consumption is directly proportional to the frequency of operation. Thus, we can reduce power consumption by increasing the sampling period T_s. We can show that without changing the anti-aliasing analog filter prior to sampling, using a digital filter of variable bandwidth BW, we can produce a properly sampled ECG signal, sampled at $2(1-1/BW)T_S$. Furthermore, larger sampling periods can be accommodated by varying the analog cutoff frequency of the anti-aliasing analog, lowpass filter. Here, we note that we do require continuous transmission of one lead of ECG signal. For the case of a moving patient, three leads will be acquired and stored on the device, but only one waveform will be transmitted continuously [8]. This will result in power savings due to the reduction in transmission power requirements.

Sensor network: Research on sensor networks is relatively recent and is currently one of the emerging fields of information technology, combining sensing with communications so as to have continuous monitoring and support the mobility of sensors [9]. For our case we have chosen to develop a Mote-based sensor network based on Crossbow® equipment [10]. In general, motes can operate using three types of topologies which are: 1) point to point topology, i.e. transmission between two notes, 2) Ad-Hoc topology which is a dynamic setup of a network structure and 3) Hybrid topology or Mesh which is a combination of both [9], [10].

4 System Architecture

The proposed network that will be used to cover the patient's house is based on motes like MicaZ™ while the acquisition of ECG data is performed through a custom created

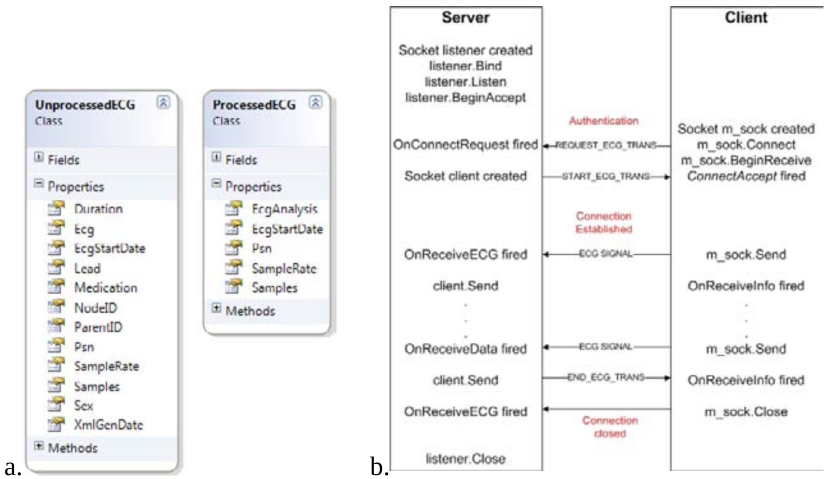

Fig. 3. a. The two classes of the XML communication Scheme Unprocessed-Processed Classes. b. Transmission protocol followed during the connection of the sites to server.

board connected to the MDA300CA™ acquisition board. Additional environmental data will be collected through the MTS310CA™ sensor board. All collected information will be transmitted to a gateway, MIB510™ connected on a Personal Computer; this is going to be the local monitoring system as shown in Fig. 1.

The in-house network will be connected to the remote monitoring system which is going to be responsible for re-evaluating the transmitted signals, local storage of the signals and display on a web interface. It will be also responsible for the notification of the on-call doctor and a relative of the child. A similar scheme will be followed for the moving patient case, where ECG signals will be collected by the same ECG acquisition device and transmitted to the remote station through a mobile communication network. The remote station will perform the same actions as above. The overall system architecture diagram is shown in Fig.2.

ECG Analysis and Transmission: For the ECG analysis needs of our project we use the open source QRS Detection software provided by E.P.Limited online at [10]. The software uses two modules. The first one is the QRS Detection which includes the QRS detection functions and the QRS filter functions. The second is the beat classification module which is used for beat classification and detection.

For the ECG signal transmission between the in-house network and the remote monitoring system an asynchronous xml communication protocol is proposed. The protocol is based on two important classes shown in Fig. 3.a. The first is the Unprocessed ECG class which is responsible to collect all the data related to the recorded ECG. The processed ECG class is responsible to collect all the data related to the analyzed ECG. The Unprocessed ECG class contains the following properties: Psn is patient's identification number, Ecg corresponds to a set of values for the ECG signal ex (200,150,175...), EcgStartDate is the timestamp of the first ECG sample value in Ecg field, SampleRate for our system is 200Hz, Samples is the number of ECG

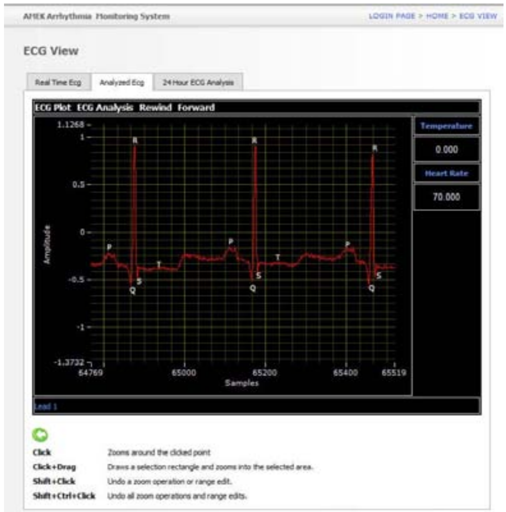

Fig. 4. Snapshot from a sample transmitted ECG signal with the analysis points

samples, XmlGenDate is the timestamp when the xml file is generated, Sex, NodeID and ParentID contain information about the sensor network, Duration is the ECG signal duration, Lead and Medication. Processed ECG class is consisted from the Psn EcgStartDate, SampleRate, Samples and EcgAnalyis properties. In EcgAnalysis field the analysis information (ex P,P,P,Q,R,S) is stored.

Based on the above classes a client in home monitoring and a server in remote motoring system are built so that after the ECG signal is recorder and or analyzed to be transmitted to the remote server. The protocol is based on the TCP/IP protocol suite and asynchronous communications. The sequence of the messages that are exchanged in the cases of Unprocessed ECG and Processed ECG signal is shown in Fig. 3.b. First the client transmits a request message to start sending ECG signal. The server receives the message and transmits a message to the client in order to start the ECG signal transmission. The connection is closed when the client receives a message to stop drop the connection. An example of the transmitted signal after the online analysis is show in Fig. 4.

5 Concluding Remarks

In this study, a prototype m-Health monitoring system for children with possible arrhythmias has been presented. As we have discussed, identification of children with arrhythmias is not an easy task and the treatment is not the same in all cases. Some forms of treatment, as is the case for some antiarrhythmia medications, increase the risk of arrhythmia (proarrhythmia effect) so it would be wrong to start such treatment without prior documentation of the problem. Another form of treatment uses implantable defibrillators. This form of treatment has given some promising results over the last few years. As we noted, it is difficult to decide who needs to be treated, not only because of the enormous cost but also because it entails a major at risk for arrhythmia and to record the type of arrhythmia that is needed before deciding on the proper management.

We hope that through the use of such a system we will be able to help in the identification of the type of problem thus helping the doctors provide the proper treatment. We have provided a basic architecture description of the system that has been developed. The system is currently being technically tested. Soon after this task, we intent to test the system on healthy volunteers. Finally the goal will be the testing of the system on non severe cases.

Acknowledgments

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An Evaluation Framework for EU Research and Development e-Health Projects' Systems*

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Abstract. Over the past years it has become evident that an evaluation system was necessary for the European Research and Competitive funded projects which are large and complex structures needing constant monitoring. This is especially so for e-Health projects. The race to complete assignments means that this area is usually neglected. A proposed framework for the evaluation of R & D project systems using ATAM, ISO 14598 and ISO 9126 standards is presented. The evaluation framework covers a series of steps which ensures that the offered system satisfies quality, attributes such as operability, usability and maintainability imposed by the end users. The main advantage of this step by step procedure is that faults in the architecture, software or prototype can be recognised early in the development phase and corrected more rapidly. The system has a common set of attributes against which the various project's deliverables are assessed.

Keywords: Evaluation, e-Health, Research and Development projects, Software.

1 Introduction

In most European Research and Competitive funded projects, the strict time plans and time limitations often lead consortia to focus mostly on delivering the proposed system without providing proper justification of the system's quality, the appropriateness and overall acceptance by the involved stakeholders. The dedicated resources spent on a system's evaluation tasks are only adequate for software evaluation and proof of concept through end users' participation in prototypes, which often happens too late in a project's life cycle. This lack of proper evaluation often hinders a project moving from research into its applied form. This is especially important when coping with the peculiarities of e-Health projects.

With the cooperation of EU partners, ALTEC has developed a unified framework aiming to evaluate the proposed architecture, the developed software, and the prototypes offered to end users of the systems that are the product of European Research and Development projects. These projects, funded by the EU,

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consist of large and complex Research structures, which involve a constellation of members, including universities, research centres and business companies who cooperate collectively on each research project.

When the expected research outcome is software the main evaluation task is to test the offered functionalities, but few, if any, resources are spent on evaluation tasks, as the consortium is usually limited by time constraints ordered by strict work plans. Yet there is the need to ensure that each offered system satisfies quality attributes, such as operability, usability, maintainability, etc, imposed by end users.

The framework for evaluating these complex structures was developed while ALTEC was participatiing in the SAPHIRE project (IST- 27074 SAPHIRE "Intelligent Healthcare Monitoring based on a Semantic Interoperability Platform" PRIORITY 2.4.13 Strengthening the Integration of the ICT research effort in an Enlarged Europe Focus: eHealth). The SAPHIRE project was to develop an intelligent healthcare monitoring and decision support system on a platform integrating the wireless medical sensor data with hospital information systems. The resulting system is employed on two pilot medical prototypes, namely the Homecare and Hospital Prototypes and the operation involves real patients and real healthcare data to be handled by the system. It was thus, a major requirement to have our system evaluated in order to assure not only its intended functionality but also its acceptance by the end users, which in this case, are the patients and the medical staff operating the system.

2 Aims and Objectives

Our aims and objectives were to assess the various deliverables of the project against a set of quality goals ordered by the system's stakeholders. To achieve this we employed the Architecture Tradeoff Analysis Method (ATAM) [1] method and the ISO 14598 and ISO 9126 2-4 standards [2].

For the evaluation of the SAPHIRE system, our objectives were:

1. To provide a unified evaluation framework able to accommodate the evaluation of architecture, software and developed prototypes.
2. To have this framework as generic as possible - not focusing only to the specific needs of the SAPHIRE project - to adopt to other projects easily without modifications.
3. To involve the end users in the evaluation process as early as possible by stating their true requirements from their perspective.
4. To exploit the results from the evaluation steps early on, providing valuable assistance to the development team.

The evaluation process follows a sequence of steps starting with the evaluation of the system's architecture under selected quality attributes. It then moves on to examine the pieces of software developed against a set of quality criteria, and finishes by evaluating the final integrated prototype through the employment of scenarios and metrics desired by end users.

3 Methodology

The proposed framework performs three different evaluations, namely the system's architecture, software and prototypes evaluation. Architecture Tradeoff Analysis Method (ATAM) was used for the architectural part, and the ISO 14598 and ISO 9126 (2-4) for the software and prototypes evaluations (Figure 1). The step sequence is described in the following paragraphs.

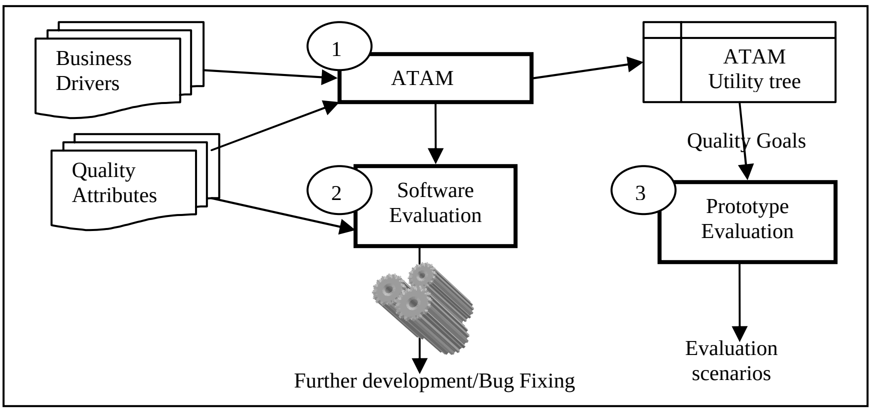

Fig. 1. The evaluation steps

3.1 STEP ONE: Evaluating the System's Architecture

For evaluating the system's architecture we employ the recognised methodology, ATAM. Apart from offering the most complete and assistive approach [3], ATAM ideally fits in our framework as it is driven by quality attributes that must be met. ATAM reveals how well an architecture satisfies particular quality goals (such as performance or modifiability), and provides insight into how those quality goals interact with each other—how they trade off against each other. Such design decisions are critical. By using this methodology, poor architecture is exposed early in the developmental sequence.

ATAM focuses on quality attribute requirements. Quality attribute characterisations answer the following questions:

1. What are the triggers/stimuli inputs to which the architecture must respond?
2. What is the measurable or observable definition of the quality attribute by which its achievement is judged?
3. What are the key architectural decisions that impact on achieving the attribute requirement?

The consequence of using the ATAM is a clarification and concretization of quality attribute requirements, achieved in part by eliciting scenarios from the stakeholders that clearly state the quality attribute requirements in terms of triggers and responses. The process of brainstorming scenarios also fosters stakeholder communication and consensus regarding quality attribute requirements.

Scenarios are the second key concept upon which ATAM is built. Based on these scenarios and refinements of quality attribute goals the team builds the quality utility tree. Utility trees translate the business drivers of the system under examination into concrete quality attribute scenarios. For example: "security is central to the success of the system since ensuring the privacy of the patients' data is of utmost importance"; and "usability is central to system's acceptance since we need to assure the patients' satisfaction."

Before assessing the architecture, these system goals must be made more specific and more concrete. The team needs to understand the relative importance of these goals versus other quality attribute goals, such as performance, to determine where we should focus our attention during the architecture evaluation.

The primary aim of ATAM, is to record any risks, sensitivity points, and tradeoff points that may be found when analyzing the architecture. Risks, sensitivity points, and tradeoff points are areas of potential future concern with the architecture. The output of this first step is a list of quality attributes and the scenarios identified in the utility tree. These, feed the next step of software evaluation.

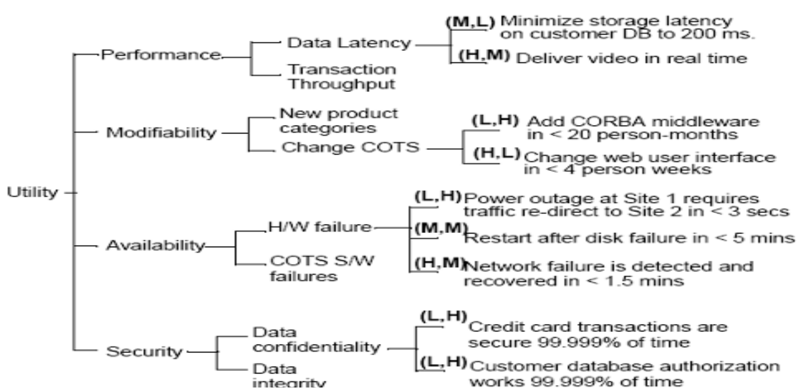

Fig. 2. An example of a Utility Tree

3.2 STEP TWO: Evaluating the System's Software

To evaluate the software in our framework, the ISO 14598 standard is used, providing an overall software evaluation quality model. This model orders how, when, whom and what is to be measured, defining as the primary tools for assessments the Quality in use measures. The process as adopted from the ISO 14598 standard involves the use of quality characteristics and it orders four stages:

1. Establish evaluation requirements
2. Specify the evaluation
3. Design the evaluation
4. Execute evaluation

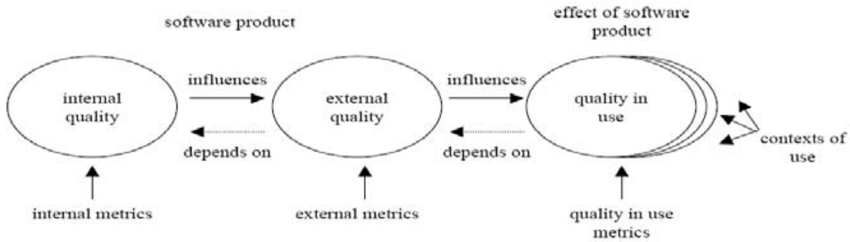

Fig. 3. ISO9126 2-4 standards

The first two stages can easily be performed by exploiting the set of desired quality attributes and through the scenarios identified in the utility tree, already accomplished in the ATAM employment. Designing the evaluation is achieved, with the help of the quality model specification, where one needs to set quality goals for the system under study. The ISO 9126 (2-4) standards are divided into three classes of evaluation requirements: internal metrics, external metrics and quality in use metrics.

The internal metrics may be applied to a non-executable software product during its development stages (such as request for proposal, requirements definition, design specification or source code). Internal metrics provide the users with the ability to measure the quality of the intermediate deliverables and thereby predict the quality of the final product. This allows the user to identify quality issues and initiate corrective action as early as possible in the development life cycle.

The external metrics may be used to measure the quality of the software product by measuring the behaviour of the system of which it is a part. The external metrics can only be used during the testing stages of the life cycle process and during any operational stages. The measurement is performed when executing the software product in the system environment in which it is intended to operate.

The quality in use metrics measure whether a product meets the needs of specified users to achieve specified goals with effectiveness, productivity, safety and satisfaction in a specified context of use. This can be only achieved in a realistic system environment. The internal and external metrics are intended for developers performing the software evaluation.

In our methodology we employ the ISO 9126 - (2 & 3) External and Internal metrics, intended for developers performing the software evaluation, and the ISO 9126 - 4 Quality in use metrics indented for the prototypes evaluation performed by the end users. The selection of measures and metrics is carried out in relation to the goals set by the evaluators and in relation to the quality goals ordered in ATAM in the previous step. The context of use is very important, as it constrains the interpretation of the quality of use. Given a certain type of user, in particular, the quality in use is then related to particular quality characteristics. We use Functionality, Reliability, Usability, Portability, Efficiency and Maintainability as the main evaluation characteristics. The development team can start the software stress tests based on the selected metrics and the results can feed the bug-fixing and further development activities ensuring the quality of the final software result.

3.3 STEP THREE: Evaluation of the Prototype

As stated above, quality in use metrics selection from the pool of ISO 9126 – 4 standard is used in the prototype evaluation. The second outcome of the ATAM employment is the utility tree which acts as a blueprint for the identification of the scenarios employed during the prototyping evaluation. The quality goals set in the utility tree, can easily be related to the architectural components responsible for delivering these goals. Having these components and their related desired quality attributes, the team can build meaningful assessment scenarios to deliver to end users in order to verify the overall system's quality, which constitutes the final outcome of the proposed framework.

4 SAPHIRE Results

The proposed evaluation framework was developed to assess the SAPHIRE system. Driven by the need to assure its overall effectiveness, we focused on measuring specific quality characteristics ordered by end users, in our case, both the patients and medical staff.

4.1 Architecture Analysis of SAPHIRE

The resulting ATAM utility tree is shown below:

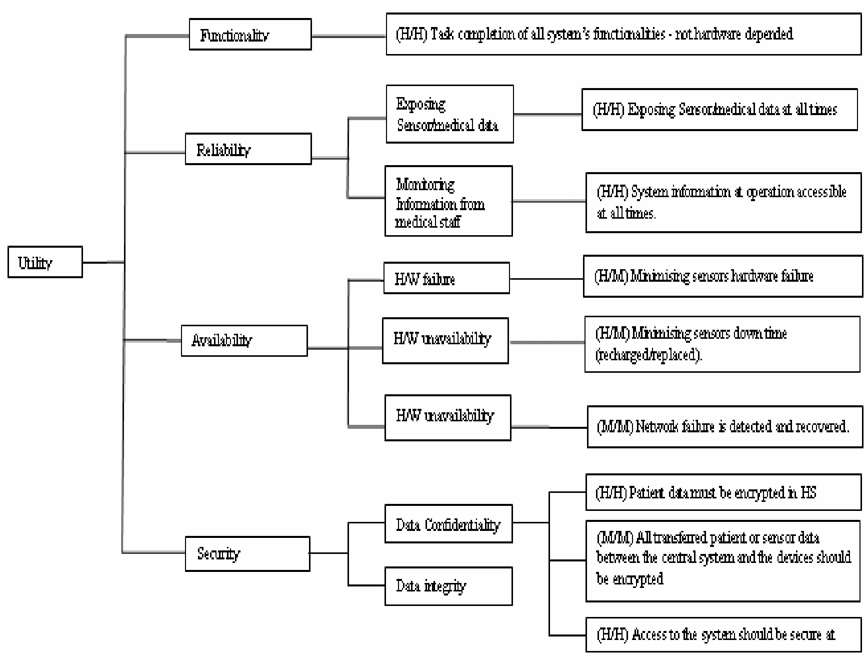

Fig. 4. The SAPHIRE Utility Tree

4.2 SAPHIRE Software Evaluation Metrics

In SAPHIRE we employed the following ISO 9126-2 & 3 metrics.

- Functionality Compliance metrics: Accuracy expectation metric, Computational Accuracy metric, Precision metric, Data exchangeability (User's success attempt based) metric, Data corruption prevention metric, Interface standard compliance metric.
- Reliability Compliance metrics: Failure density against test cases metric, Failure resolution, Breakdown avoidance metric, Incorrect operation avoidance metric, Availability metric, Mean down time.
- Usability metrics: Operation Understandability metric, Understandable input and output metric.
- Effectiveness Compliance metrics: Task effectiveness, Task completion, Error frequency.

4.3 SAPHIRE Prototype Evaluation

We selected metrics that would be easy to apply and to measure. Our metrics were user-oriented, meaning that they aimed to monitored the user's behaviour by using the system in the way each scenario dictated. We adopted from the quality in use metrics pool the Effectiveness, Efficiency and Satisfaction metrics categories.

- Effectiveness: Completion Rate, Errors, Assists.
- Efficiency: Task time, Completion Rate/Mean Time-On-Task.
- Satisfaction: Questionnaires to measure satisfaction and associated attitudes were built using Likert and semantic differential scales. Depending on the case, whether an external, standardized instrument is used or a customized instrument is created, it is suggested that subjective rating dimensions such as Satisfaction, Usefulness, and Ease of Use be considered for inclusion, as these will be of general interest to customer organizations.

5 Business Benefits – Conclusions

The main business benefit behind our approach is the focus on the end-users' quality requirements. These can be translated into quality goals which will drive different evaluation tasks (architecture, software, prototypes) performed by different stakeholders. We manage to increase the confidence of developers, while most importantly minimise the end users involvement (in our case real patients' capacity and medical staff's time-restricted resources).

In employing the framework we took advantage of the work performed in already completed tasks and work packages, namely those of requirements engineering. Employing ATAM was a fairly easy task because it already had a set of system's requirements and architecture analysis. The main difficulties faced were primarily in persuading developers to learn how to employ the ISO 9126 2-3 measurements and metrics to test the delivered software components.

For the SAPHIRE, and similar eHealth related funded projects, the employment of this framework provided a clear evaluation path to be followed by partners according to their role in the development product life cycle thereby easing testing and validation tasks, while providing more time to focus on the critical health/technological issues to be tackled, and thus able to allocate more effort and money to development and refinement tasks.

In addition, we believe that the application of the proposed framework is not limited to e-health related systems. The core concept is the early identification of the desired quality attributes that the system being devised should satisfy. Having these, we can apply the framework to assess the architecture, the software and the system prototypes against the appropriate measurements and metrics selected accordingly from the pool of ISO 9126 2-4 standards. We acknowledge that further work should focus on extracting the quality attributes from the requirements engineering phase in a more automated and traceable manner. Currently we are in the requirements elaboration phase, planning to build a software toolkit, able to offer the proposed evaluation steps and approach. It is our intention to offer this toolkit to partners participating in EU-funding consortia once the project is finalised and critically evaluated.

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Health@Home – An e-Service Model for Disease Prevention and Healthcare in the Home

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Abstract. The ageing of the population, the growth of chronic diseases, and the explosion of healthcare costs jeopardise the sustainability of healthcare systems in many European countries. This opens opportunities for innovative prevention and healthcare services supported by information and communication technologies (ICT). The natural focus for providing such services is the home. However, the e-health services provided in the home so far are limited in scope and fragmented. This paper suggests a comprehensive service model for home-based e-health services in Europe, which aims to overcome the current service fragmentation. The Health@Home model integrates disease prevention and healthcare for different groups of citizens at different stages on the health scale. The technical challenge of this model is the national and Europe-wide integration of heterogeneous systems and services in a way that makes them reliable and easy to use for all citizens, particularly those with low technical abilities and severe impairments.

1 Introduction

The ageing of the European population has a dramatic impact on healthcare systems in Europe. The cost of treatment has risen to a level, which threatens the functioning and financing of the national healthcare systems. At the same time, these expensive healthcare systems are decreasingly capable of providing the level of care that citizens need, especially elderly citizens and patients with chronic diseases.

The growth of the number of patients with chronic diseases is not only driven by the growing number of elderly people. It is also driven by an unhealthy lifestyle in developed European countries, which affects citizens in other age groups as well, causing further financial burdens for the healthcare systems. According to a Eurobarometer survey done in 2007, already 29 percent of EU citizens have chronic diseases, 5 percent more than in 2005 [1].

The current healthcare system is ever less able to cope with these challenges in a financially feasible way. The cost of treatment of chronic diseases alone makes it necessary to look at new ways of providing care. Empowering patients in order to take

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care of their health is a consistent and effective way to overcome these challenges, reducing the dependency on frequent support by healthcare professionals. The most effective way to achieve this is via ICT-enabled health services, and the best place to provide those services is the place where citizens live, in their homes.

The home offers the perfect environment for providing e-health services, either for prevention, continuous care, or treatment of chronic diseases: the environment is favoured by patients and has in itself a positive impact on the mental well-being of patients, compared to hospitals, practices of general practitioners, and care facilities. The evolution of ICT has reached a level that makes the cost-effective provisioning of e-health services in the home a realistic option.

ICT-enabled services in the home are especially important for the growing number of elderly people with chronic diseases, who live independently in their private homes, but lack the support of relatives, while their conditions are not bad enough to be eligible for financing of professional care services by the healthcare system or hospitalisation.

On the other end of the health scale, there are young and middle-aged people with chronic diseases or – due to their life style – the risk of getting chronic diseases. They could benefit from ICT-enabled health information, consulting, and monitoring services as a prevention mechanism.

2 Stakeholders in Home-Based Prevention and Healthcare

The main stakeholders in home-based prevention and healthcare service scenarios are the citizen/patient, healthcare professionals (general practitioners, doctors at hospitals, homecare providers, etc.), ICT service providers and network operators, providers of health monitoring and ICT devices, the national healthcare service and health insurance companies.

There is a paradox situation in Europe today: a growing share of citizens has broadband connections and feature-rich communications and consumer electronics equipment, but only very limited access to e-health services. The few existing healthcare service platforms are limited to special medical conditions (e.g. diabetes or chronic obstructive pulmonary disease – COPD) and proprietary devices. The user access to services is mostly through the Internet via PCs or via plain old telephony services. Patients with chronic conditions have already some health monitoring devices, like, e.g., blood pressure meters, at home. However, the access to the collected data is usually done via proprietary protocols and applications, which makes it almost impossible to connect these data to any kind of electronic health support service. Some services for elderly patients, like, for instance, half-automated emergency call services, rely on telephony and offer only a limited scope of support.

The reasons for the lack of prevention and healthcare services in home networking are mainly related to technical and organisational issues. On the technical level, the integration of heterogeneous services and devices via a home platform has not yet been fully achieved. On an organisational level, there is a lack of coordination between the major stakeholders in home-based prevention and healthcare service scenarios.

In order to implement the proposed Health@Home service model, the current stakeholder roles have to change, and integration on the technical and organisational level has to be a central concern.

In the envisaged Health@Home service model, patients will become empowered to take control and responsibility for their own well-being to the extent possible, with health support services being available and accessible when needed.

3 The Health@Home Service Model

In a number of EU-funded research projects, like, e.g., CAALYX – Complete Ambient Assisted Living Experiment [2], scenarios for ambient-assisted living (AAL) in an intelligent home environment have been explored. There are also special projects on AAL scenarios for the elderly, like, e.g., OLDES - Older People's e-services at Home [3]. First commercial services in this area are already on the market [4]. Both, research prototypes and the few commercial services, are fragmented solutions for limited groups of patients with a very limited scope for interconnectivity.

The Health@Home approach goes beyond current models by providing e-health services in the home comprehensively, including prevention, treatment-related monitoring and alerting in an integrated framework driven by the patient needs.

The proposed model is based on an open, secure Health@Home service platform that integrates information from different communication and monitoring devices. In order to achieve its purposes, the platform will have a number of essential characteristics:

1. The platform will be based on open standards, in order to make the service provisioning easily extensible, easily accessible for users, and independent of specific home user devices.
2. The platform will enable multimodal access via multiple devices. Especially elderly patients will often not be able to handle their health information via a common PC, and in some cases, even easier accessible text-based systems are not usable for them due to impaired vision. Thus, voice-controlled access will be a key feature, e.g. via easy-to-use handheld devices, or intuitive pictorial-based access and service control via highly familiar devices, such as, e.g., the television set.
3. The platform will enable advanced service scenarios, which perform the collection of health monitoring data, e.g. from blood pressure meters or heart rate meters, in a way that does not require the active intervention of the patient.
4. The platform will access electronic patient record information, in order to match monitoring data and drug prescription information with the patient's medical history and medication record.
5. The platform will be customisable to the personal needs of the user and patient. This includes also the handling of health data collected via health monitoring devices and sensors in the home, granting the necessary privacy levels when exchanging information in the home network or via the telecommunications provider infrastructure. Users will, by default, have the capability to determine who should obtain access to the health data that are stored on the remote Health@Home server. In addition, users will have the option to store the data locally.
6. The platform will be comprehensive, usable by all users (e.g. patient, relatives, homecare personnel) and adaptable to different care conditions. A modular and adaptable approach will be adopted in the platform development ranging from preventive care, with a focus on risk monitoring and prevention (e.g. overweight, high blood pressure), to chronic disease monitoring and treatment.

7. Mobility aspects will also be covered, especially concerning chronic diseases. Most chronic diseases, like chronic heart failure and COPD, require permanent monitoring and supervision by either heart or pulmonary specialists. Collecting and automatically transmitting physiological measurements to the platform via mobile devices is, thus, very important for the patient's safety and well-being.
8. Portability of the platform. Services running on the platform will be portable as much as possible, and this imposes several requirements on the home network.

Figure 1 gives an overview on how the Health@Home service will work.

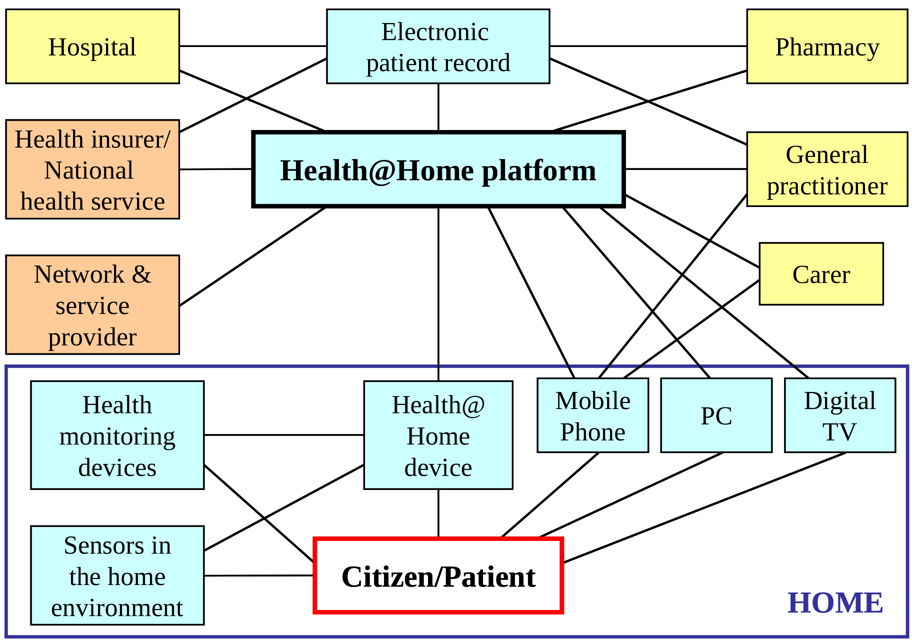

Fig. 1. The Health@Home service model

At the centre is the citizen/patient in his home, who – depending on his health status – can use a variety of monitoring devices and sensors in his home environment to collect and analyse his personal health information. All the data will be wirelessly sent to a Health@Home device that has an easy-to-use multimodal interface. The device is connected via a wide area network (WAN) and a home gateway to the Health@Home platform, a remote data server. It will be important to integrate platform operation and maintenance with the set-up of the home network, in order to achieve a maximum synergy and cost-effectiveness in the Health@Home business model. Network service providers are in a key position to embrace this challenge, due to their technological expertise and the established access to the citizens' homes. The service offering could be financed by the national healthcare authority or a health insurance company, depending on the healthcare system in the respective country.

The platform accesses the electronic health record of the patient, which is stored on a protected server under the auspices of the national healthcare authorities. The platform would both match the patient's monitoring data with the data in the patient record and also provide the monitoring data to the general practitioner or doctors at the hospital, who would, in turn, be able to update the electronic patient record, if required. Other actors in this model would be the pharmacy, which would be involved via e-prescription and which could also offer a service for automatically delivering required drugs to the home, if the patient cannot go to the pharmacy himself. Finally, in a homecare scenario there is the carer, either a nurse or a relative, who would also have access to the platform and could check the monitoring data, e.g., would receive an alert, if a sensor indicates that the patient is in a critical condition.

Automated alerts, e.g. medication reminders, could be triggered by the platform, based on the data provided by the doctors treating the patient. For citizens who just need the platform for prevention, no health professionals would have to be in the loop. He or she could just send vital data, e.g. blood pressure, heart rate or weight, to the platform, which would send back an automated analysis of these data, combined with specific health advice.

In the ambient-intelligent environment of Health@Home, sensors play an important role for monitoring the patient's vital functions and general well-being, as figure 2 illustrates [5]:

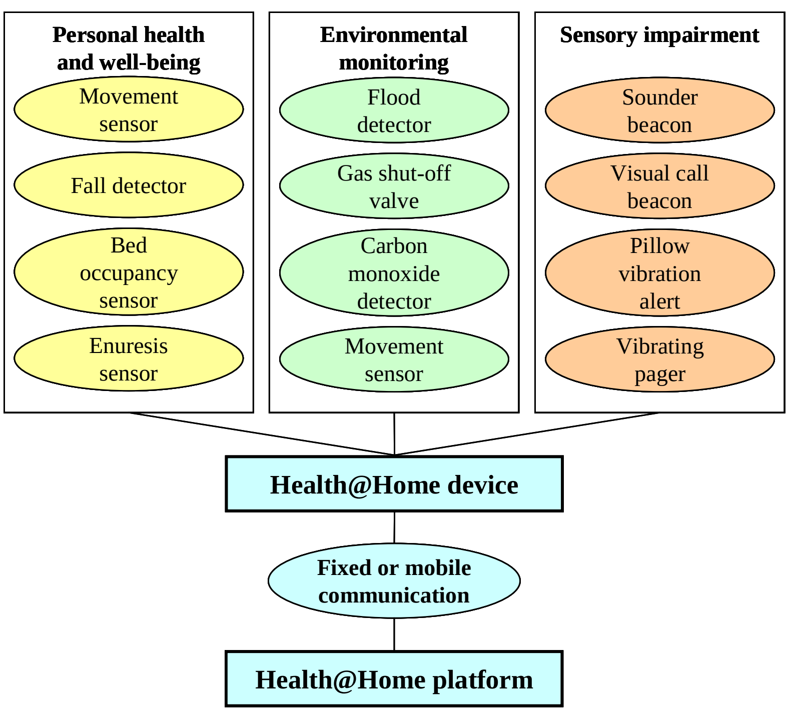

Fig. 2. Sensors in the Health@Home services model

4 Feasibility and Mid-Term Implementation Prospects

The Health@Home model's feasibility depends on many factors, like technology, standardisation, interoperability as well as privacy, security, and user acceptance.

Integration of technologies and devices

The integration of heterogeneous technologies and multiple devices in the home is currently being driven by a number of home networking projects that promise to provide high-speed data access anywhere via any device in the home [6]. Additionally, the Continua Health Alliance is currently working on developing and promoting open standards and guidelines that enable interoperability of health monitoring devices from different suppliers [7]. This type of integration is one of the pre-conditions for making the Health@Home model feasible.

Standardisation

Standardisation in the field of e-health is not yet mature. There are a number of relevant standards, like, for example, HL7 – Health Level Seven on clinical and administrative data and ISO 27799 on security management in health. However, the choice and implementation of these standards are not yet unified, and for electronic patient records, no widely agreed standard has emerged yet.

In February 2008, the three European standards organisations CEN, CENELEC, and ETSI announced the launch of the joint project "e-health-INTEROP", which addresses the requirements of the European Commission mandate on standardisation in the field of e-health. This mandate (M/403) aims to provide a consistent set of standards to address the needs of future healthcare provisioning.

Interoperability

A crucial factor for the feasibility of the Health@Home model is interoperability. The effectiveness of the model largely depends on standardised, interoperable electronic health records (EHRs), which are not yet in place in almost any European country.

In a Recommendation issued on 2 July 2008, the European Commission has made the cross-border interoperability of electronic health record systems a priority, with the target of achieving EU-wide interoperability by the end of 2015 [8].

The goal of interoperability is the smooth flow of information, which is also an important requirement for the Health@Home model.

Mobility

In order to provide seamless service continuation, when the patient is on the move, it is important to integrate mobile capabilities into the Health@Home platform. Especially patients with chronic diseases need permanent monitoring of vital functions, while they are out of their home. The monitoring data should be collected and processed via the Health@Home platform, in order to trigger certain actions, e.g. medication reminders or doctor alerts, if critical values are reached.

Privacy, security and data protection

The smooth flow of information entails critical challenges for privacy and data protection. Personal health data are very sensitive and critical for user acceptance, and the protection of these data has to be guaranteed, if the Health@Home model shall succeed. It will be crucial for the feasibility of the Health@Home model to develop privacy-enabling technologies which provide differentiated access controls that are easy to handle and transparent to the user.

Scalability and reliability

From the start the platform must be designed for a large number of users. A platform that will serve millions of people will have to adhere to high standards concerning scalability and reliability. As the services running via the platform are critical, high levels of quality of service under any conditions must to be ensured.

Barriers for deployment

We believe that the technical challenges discussed above can be overcome in the mid-term. However, there are other non-technical barriers which could have a severe impact on the large-scale take-up of the Health@Home service model.

The three most relevant areas in which existing barriers need to be addressed are regulation, finance, and user acceptance.

Health regulation in most EU countries is not yet ready for an innovative e-health model like the Health@Home service. This is particularly relevant for the roles of hospitals and general practitioners, which would change significantly in the Health@Home model compared to the current situation. What is the legal basis for doctors performing tele-monitoring and tele-consulting via an e-health platform? How would doctors be remunerated for this? What are their liabilities if something goes wrong? These are some of the open questions that need to be addressed in the necessary revisions of European and national regulations on e-health.

The other barrier is finance. In the mid- to long-term, the Health@Home service model would lead to significant cost savings, due to better prevention and less time spent by healthcare professionals for in-patient treatment, while maintaining and increasing the healthcare quality. However, considerable investments would have to be made that would not lead to cost savings in the short term.

Finally, user acceptance could be a critical barrier. There is a general reluctance of doctors, because any e-health models, including remote monitoring, are not clearly regulated, so besides unclear remuneration there would be legal risks. In addition, there is widespread resistance of healthcare professionals to change – they envisage additional effort, but no clear benefits for themselves.

According to a poll by British newspaper “The Guardian” done in November 2007, almost 60 percent of general practitioners in the UK are unwilling to upload their patient data to a proposed national database. They fear that "sensitive personal data could be stolen by hackers and blackmailers" [9]. According to research commissioned by the UK Medical Research Council, the general public shares this feeling [10].

The main reasons for the widespread reluctance by patients towards e-health are that they feel overwhelmed by technology or they fear their private health data are exposed to abuse.

Implementation issues

There are a number of further issues that need to be addressed before the implementation of the Health@Home service model. These issues include questions like: Who will be the responsible for the maintenance and operation of the service platform? How will charging and billing be handled? How will the legal and contractual relations between healthcare and social welfare authorities as well as the platform service provider be organised?

Solving these issues requires the shared vision and political will to establish a Health@Home service on national level with the perspective of integrating the national platforms on a European level.

5 Conclusions

The Health@Home service model provides a promising opportunity for integrating prevention and healthcare in the home environment. The model goes far beyond current models that are too limited in scope and accessibility in order to serve a broad range of patients and to serve patients with multiple chronic diseases that are today not necessarily served via the same e-health platform.

Implementing the Health@Home service model will be challenging, as a number of technical and organisational issues would have to be solved in order to make it happen. However, the growing cost pressure and the growing demand by patients, especially elderly patients, is expected to accelerate the organisational changes that are required to realise a patient-empowering Health@Home service.

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Agent-Based Simulation of Emergency Departments with Patient Diversion

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Abstract. We describe an agent based model of an emergency department and its utility for evaluating workflow and assessing patient diversion policies. The overall goal of the research is to develop tools to better understand and manage emergency departments. There are several modes in which agent based modeling tools may be of benefit. In a self contained manner the operation of an emergency department can be modeled. In this mode, policies such as staffing could be changed and the effect on parameters such as waiting times and throughput could be quantified. In an extended version, multiple emergency departments can be modeled and would allow for the evaluation of ambulance or patient redirection policies. In either case we also suggest an effective means of augmenting the simulation with empirical data collected using a proximity location and tracking system within an emergency department. Our agent based model allows for a simulation of a number of emergency departments and introduces a method of extracting real time patient data from emergency departments throughout a city allowing for the evaluation of patient diversion policies.

Keywords: Agent based modeling, waiting time reduction, ambulance redeployment, emergency department, and bio-inference.

1 Introduction

Hospitals represent one of the most promising areas where agent based modeling may be seen as an effective tool in evaluating policy and improving efficiencies. In many cases, the operations of an emergency department are over taxed and may not be guided by optimal policies. Although policies evolve over time and efforts are made to reduce wait times etc. often there is little quantitative analysis or feedback in the process. Using agent based modeling an emergency department can be modeled and in this manner better use of resources can be made possible through identification of anomalies and bottlenecks which may be difficult to detect otherwise.

In addition, technologies are emerging that will be leveraged by Hospitals to improve patient care. Two of the more obvious technologies and applications include

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inter Hospital tracking and internetworking. These technologies will also allow for a more distributed approach to managing a number of interacting emergency departments. Along these lines the emergency department simulator can be used to evaluate ambulance redirection or diversion policies.

The research presented here provides a specific emergency room example application and an extension to a wide area Hospital/ED/Ambulance and patient diversion scenario. Section 3 discusses work completed to date on an open source visualization, simulation, and wait time forecasting simulation suite. Section 4 presents simulation results for the scenarios discussed above, for use in evaluating workflow within an ED, and for use in patient diversion policies.

2 Applications

The applications discussed below are of increasing interest here and elsewhere. Although agent based modeling of an emergency department is of utility on its own [1], it is of considerably more utility when combined with tracking technologies and networking capabilities. Specifically our agent based model is a distributed model across a number of regional hospitals with emphasis on utilizing data collected in real time. Another novelty is the use of congestion avoidance algorithms from Telecommunications Engineering redeployed as a model for evaluating patient diversion policies. The following applications are included as context for which the emergency department simulator is well suited.

2.1 Local Area Patient Tracking

An application we are working on is directed towards monitoring or estimating the location of patients as they enter an emergency room until treated and released. This is an extremely active area of research and concern for both the general public as well as practitioners. In the following scenario, emergency department simulation is enhanced with empirical data collection technologies [2].

In one scenario a patient is tagged with an RFID tag when registering at emergency, an RFID reader at the desk records the event. As the patient enters the waiting area another reader reads this event. The event and reader location are recorded at an Hhost (Hospital host subsystem). Data logged by the Hhost (timestamp, tag and reader ID) would be uploaded via the nearest Wi-Fi access point to be relayed to CORE (Central Observation and Reporting Environment). Once stored at the CORE it can be made available for augmenting the agent based simulator, mining or made available over the Internet to other stakeholders. In certain circumstances the information can be made available to the public such that they may be better informed as to which emergency department or clinic they may choose to attend. A specific example would be information concerning wait times at facilities for injuries such as broken bones and whether or not a physician was on staff to set a break at that time.

Figure 1 illustrates an emergency department with RFID readers deployed strategically throughout the area capable of reading and logging patient tags for subsequent uploading to a more central network service.

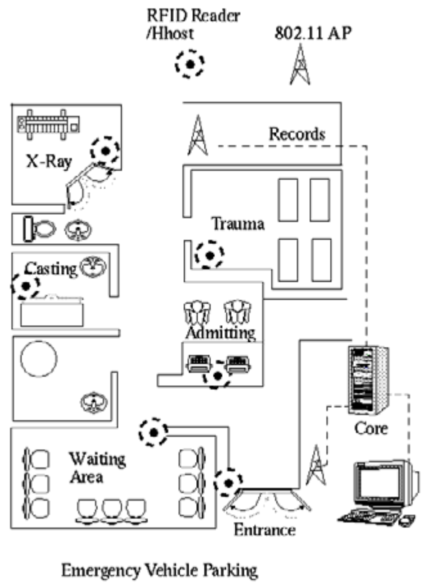

Fig. 1. Schematic of tagging locations in a Hospital Emergency Facility

In the future it is also conceivable that a patient's tag could be updated during treatment such that a more complete record of a where bottlenecks occur could be extracted. For example, upon receiving an X-ray the RFID tag could be programmed to store this information and subsequently uploaded to CORE when read by the next reader encountered. The tag could also be programmed at admitting indicating the general type of aliment or complaint for more complete although anonymous data collection and analysis.

2.2 Wide Area ED Scenario

In a wide area hospital/ED/ambulance scenario the basic CORE functionality would scale and encompass alternative communication modalities. At present, our prototype CORE is designed to support wide area networking having evolved from a geographically dispersed event management system [3]. Also as CORE is IP centric, security issues are largely resolved using VPNs and encryption standards associated with IP. The following figure illustrates the basic components and agents in the extended framework.

Figure 2 illustrates a wide areas scenario incorporating participation hospitals and emergency service vehicles.

In the wide area scenario (Figure 2) each hospital emergency department would be equipped as in Figure 1 with data extracted from RFID proximity location systems augmenting the agent based modeling.

More proactive modeling extensions include the ability to notify and receive information from ambulances and other emergency vehicles. The actual communication services likely would be over GSM or similar communication infrastructures. Here

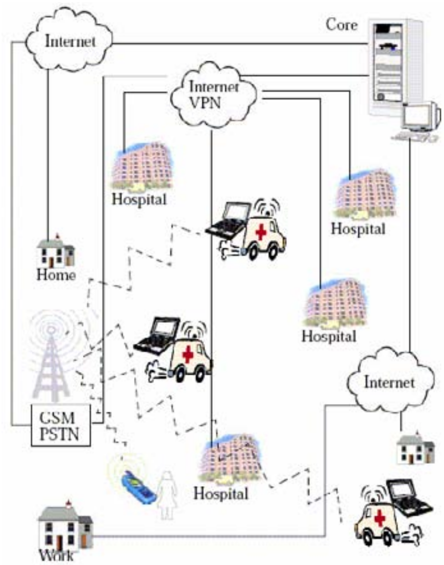

Fig. 2. Wide area deployment of the framework illustrating the major stakeholders or agents

these services can be modeled as messages between agents and the platform would be used to assist in optimizing ambulance diversion policies. Other types of considerations required would be in the estimation of travel time as these factors would significant in an effective model. Although not addressed here, with the proliferation of GPS and mapping technologies, these estimates can again become empirical inputs to the multiple emergency department simulation.

At present ambulance diversion is principally based on best effort reporting and operating in good faith based on regional guidelines, an example of which can be found at [4]. We suggest that in addition to these heuristics, emergency department modeling can benefit from algorithms more commonly associated with the Internet and congestion avoidance schemes that deal with overcrowding of routers. As an example, we have adapted the Random Early Detection (RED) algorithm [5] as a candidate for consideration when attempting to optimize ambulance or patient redirection. This is an ideal initial algorithm for adaptation as it has many of the attributes well suited to improving system throughput. RED accommodates limited bursts and can be effective even when there is limited sharing of information between emergency departments. In our case, we would be using RED as a model for redirection based on emergency department congestion information being made to potential patients/ ambulances to model the redirection.

3 Visual Simulation Suite

As mentioned in section 2, we are developing an object oriented (OO), open-source, visual simulator which could be used with data gathered from the previously discussed architecture, and may be used to analyze and forecast emergency department waiting times. The simulator was written using C++ and makes use of the Qt4 API for cross platform windowed applications [6]. By virtue of Qt4 itself being open-source as well as our code, once the source is released in Beta stage, our project will benefit from other researchers customizing and extending our code. Neither of these things would be possible had we used an off-the-shelf proprietary solution instead of an open-source paradigm. Qt4 also allows us to deploy the simulator on Windows, Mac, or Linux. A screenshot of the simulator window is shown in Figure 3. The spatial aspect of the visualization reflects the spatial nature of the underlying data we will collect.

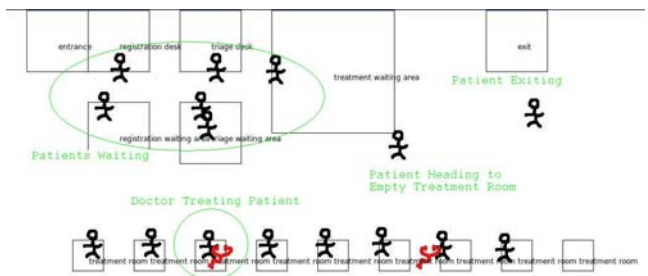

Fig. 3. Screen Capture of the Basic Simulator

3.1 Emergency Department Model

The aspects of the emergency department treatment process which we are interested in modeling are depicted in Figure 4. Patients arrive either by ambulance or walk in. Patients in need of immediate care are sent straight through to the treatment area. All ambulance arrivals are considered to be in need of immediate care, as well as some small fraction of walk-in patients.

Walk-ins that do not require immediate care proceed to the registration desk. If the registration desk is busy with an earlier arrival, the arriving patient then waits in a queue. Once the registration process is complete, the patient proceeds to the triage

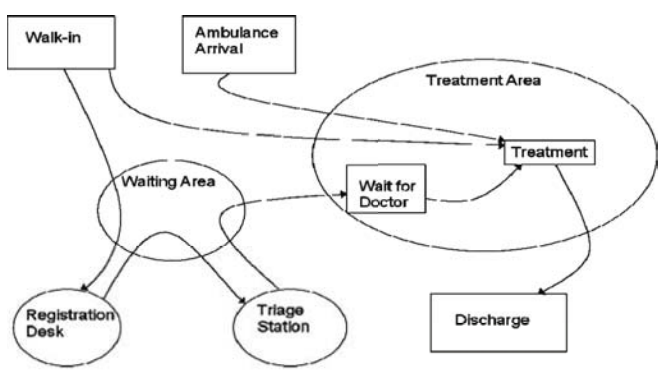

Fig. 4. Model of Emergency Department Patient Service

station. Again, if the triage station is busy, the patient waits in a queue. The nurses at the triage station will assign the patient a priority based on the severity of their condition. The arriving patient then waits with other patients in what is effectively a priority queue to be assigned a treatment room.

Once assigned a treatment room the patient waits for a doctor to come around in order to receive treatment. It is assumed that doctors will treat the patients in order of urgency, then in order of arrival. Upon completion of the treatment, the patient leaves the system, and both the treatment room and the doctor become available for another patient.

3.2 Basic Architecture

The simulator maintains an instance of the erWorld class which keeps references to all the simulated objects described in this section. Each erWorld represents one emergency department. To implement the Wide Area Scenario to simulate and investigate ambulance diversion policies suggested in section 2.2, and further discussed in section 4, we would have numerous instances of erWorld. The flexibility and reuse of code made possible by the OO architecture makes this possible by subclassing or extending existing classes to allow communication between instances of erWorld. As mentioned, each erWorld maintains a collection of patient generators, agents representing nursing stations (registration, triage), patient agents, and doctor agents which represent corresponding aspects of the model discussed earlier. A special erController agent is used to mediate patient flow through the emergency department process. Creating subclasses of erController is necessary to be able to handle variations on the basic emergency department processes in order to reflect different policies for individual emergency departments we are trying to model. For example, one would create a subclass of erController for an emergency department that allows for bedside registration for all patients versus an emergency department that requires most patients to register at a desk (as per current implementation). The classes that represent doctors and the nursing stations may also be subclassed to reflect procedures that vary between emergency departments. Patients too can be subclassed should the need arise.

As shown in Figure 3, we have the ability to place functional areas of the emergency department at arbitrary locations. However, it is our goal to eventually overlay the locations on the actual floor plans of the emergency departments we wish to simulate.

At every simulated time step all relevant agents are refreshed. For example, patients move between nursing, waiting, and treatment areas, as well as track the time spent in each activity. Doctors move to occupied treatment rooms and treat the patient within. Nursing stations count down the time required to process patients for the relevant activity. Patient generators model a Poisson arrival process for each patient class (i.e. classified by urgency of care required). At each time step each decides whether to introduce a new patient. Currently, since we have yet to collect data, we base our arrival rates and service times on estimates obtained by other researchers [7]. However, it is our goal to have the simulator driven by real world data, collected in real time, such as that proposed in section 2 where RFID proximity location system data would be used to augment the simulator.

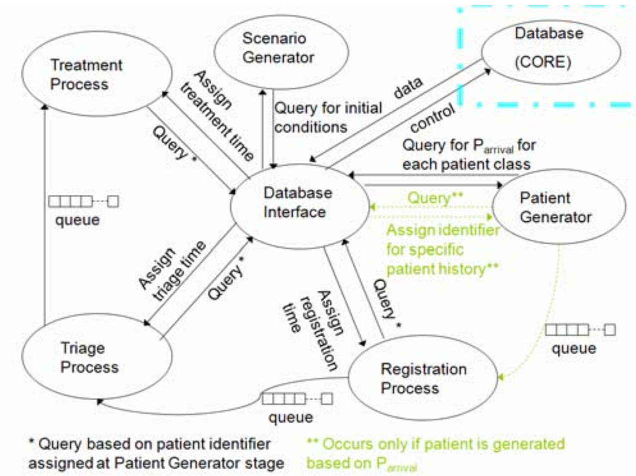

Fig. 5. Data Flow for Simulation

3.3 Data Driven Simulation

Once collected, and after some additional processing, data can be used to drive the simulator by employing an intermediary database interface class, which insulates the simulator code from the specific database implementation used. Processing may include sanitizing the data to ensure patient anonymity, and determining the arrival rate for the appropriate time of day and time of year. Figure 5 illustrates how the gathered data may be used during the course of the simulation.

When the simulation is started, the state of the simulated emergency department is seeded with the current state of the actual emergency department as inferred from the most recent data sent to CORE from the MHosts. The Patient Generator periodically queries for current arrival rates for each simulated patient class as illustrated in Figure 5. Those rates are used at subsequent time steps to determine whether a patient of a particular class arrives at that time step. If a patient arrives the agent is assigned a random patient history of the appropriate patient class upon creation and that history is used to determine service and treatment times for that patient. Note that times spent in queues are determined by the current state of the simulator, i.e. the number of patients waiting ahead of that patient, rather than the patient history.

In order to forecast future patient wait times, the simulation can be run into the future a number of times, keeping track of the wait times experienced by patients arriving at future times – until some reasonable level of confidence is reached. During this process the visualization can be disabled in order to speed multiple trials.

Prediction based on modeling and simulation is extremely difficult and potentially error prone. Confidence can be enhanced as the system is in operation and predictions tracked. Our conjecture is that the model of individual or interacting emergency departments augmented with whatever available empirical data is available would still be better than open loop policy decision making.

4 Simulations

In this section we describe two experimental results that suggest the utility of the discussed simulator for making informed policy decisions. The first scenario we investigate, while simple, illustrates the effects a policy decision has, such as changing staffing levels, using multiple performance metrics. In the second scenario, despite not having an actual RFID data collection system in place, we attempt to model what impact it would have if the infrastructure were in place to gather and disseminate ED utilization in real time. This would have the effect of informing the Ambulance Service as well as individual citizens (perhaps through a web portal) of the real-time status of EDs in the city in order to make better informed decisions about which ED to visit (based on current and projected wait-times).

4.1 Staffing Change Scenario

In this scenario we simulate the basic ED scenario mentioned above, and with Triage Classes, Service Times, and Patient Arrival rates based on [7]. We compare 3 different staffing scenarios of 2, 3, and 4 doctors working in the ED. The simulation was allowed a "warm-up" period of 24 hours, then observations were made during the following 24 hours. Ten independent trials were run, treatment queue length and doctor utilization were averaged, while individual patient waiting times are shown unaggregated. These results are presented in figures 6, 7, and 8, respectively.

From these figures we see that intuitively they seem reasonable. Figure 6 shows the average number of patients waiting for treatment as a function of time (in seconds). For example, as seen in the case of an ED with two doctors the patient queue continually increases with time as the ED is clearly under-staffed. In an ED staffed with four doctors

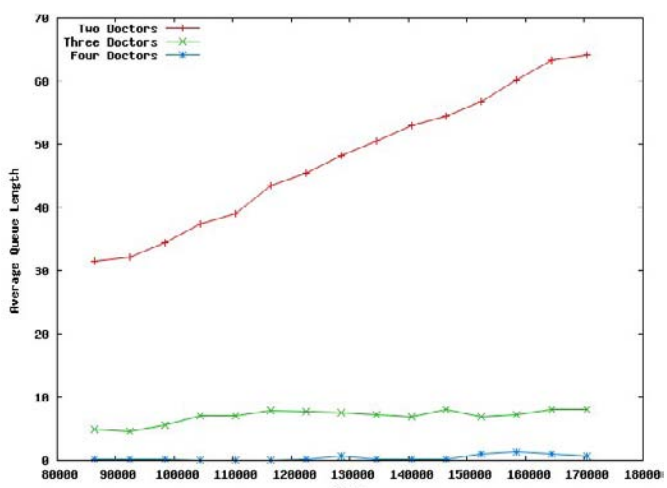

Fig. 6. Average Queue Lengths for Varying Number of ED Doctors on Duty

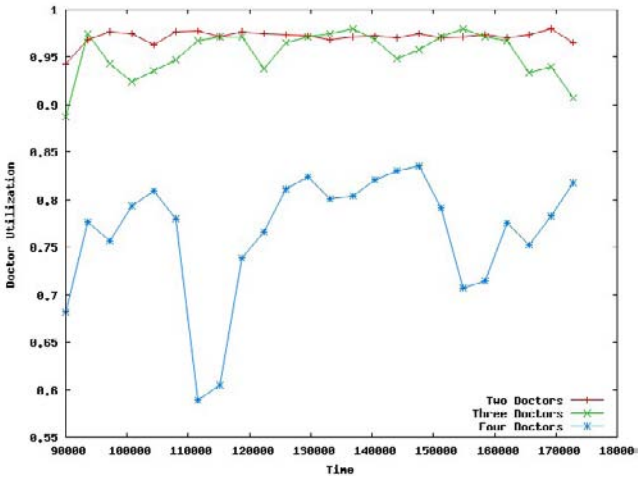

Fig. 7. Average Doctor Utilization for Varying Number of ED Doctors on Duty

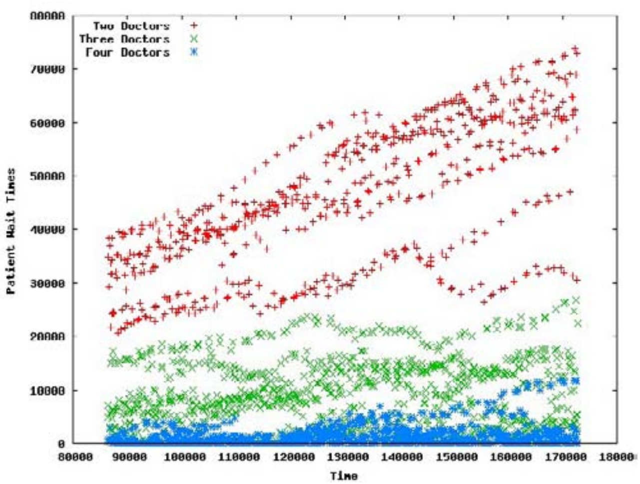

Fig. 8. Patient Waiting Times for Varying Number of ED Doctors on Duty

the patient queue is nearly zero however, Figure 7 illustrates that the doctors are under-utilized. This suggests that for this scenario, unless it is critical to have nobody waiting for service, resources would be better allocated elsewhere rather than adding a fourth doctor. It is interesting to note that in Figure 8 each data point is an individual patient, albeit simulated, passing through the ED - in which case outliers would perhaps correspond to patients which waited an unusually long or short time. For policy makers, it may be easier to empathize with individual patient cases than with a standard deviation or other such statistical measure.

4.2 Data Infrastructure Scenario

In this section we attempt to model the impact of collecting real-time ED status using the RFID based framework discussed in section 2, then making available the real-time ED status to Ambulance operators and the public at large on a city-wide scale. Since this system is not yet in place, we borrow from computer network engineering the well established technique of Random Early Detection (RED) [5] to model this process. Random Early Detection is a method of network congestion management, whereby senders of data over the network (typically the Internet) are implicitly notified of network congestion by having their data packets (data over the Internet is divided into discrete chunks, called packets) probabilistically dropped from network queues. To avoid oscillation between intense bursts of traffic and choking off traffic entirely, the rate at which these packets are dropped is ramped up gently after a certain threshold in the queue length is reached. Similarly, in our ED model, we set a minimum threshold, below which ED queue lengths are considered acceptable by everyone and no dropping occurs. The rate at which patients are dropped increases linearly with queue length until some maximum threshold is reached, past which the drop rate remains constant. Since we consider "dropping", or turning away patients, as unacceptable our model instead considers a drop to be a patient being redirected to another ED. The mechanism for this is either self-redirection to another ED or an Ambulance being redirected by a central dispatcher. Two modes are considered, one where patients are redirected to a random ED with uniform probability, and one where patients are probabilistically redirected to an ED based on the ratio of doctors to patients waiting. In the latter case, this results in EDs that are less busy having a higher likelihood of patients being redirected there. This reflects an assumed patient preference for shorter waiting time, and also demonstrates the utility of having city-wide ED status information disseminated. This is contrasted with the former case, where patients are simply guessing as to which ED is a more preferable alternative without any guidance whatsoever.

To ground our simulations as much as possible in reality, we made use of a report on Emergency Department usage in Winnipeg released just prior to this writing by the Manitoba Centre for Health Policy [8]. There were 185,659 ED visits in Winnipeg among 6 Hospitals, the breakdown of which by CTAS [9] triage level roughly corresponds to the triage levels used in [7]. Since we don't have data on treatment times we thought it plausible to use the distribution of treatment times based on triage level from [7]. To date, we have no data on variation in patient arrival rate, based on time of day, day of the week, time of year, or variation between individual EDs so we assume that the rates are uniform for these variables. It should be noted that these types of variations can be easily incorporated in the simulator. With the information presented above, it was possible to estimate arrival rates of patients for each triage level at each simulated ED. An arbitrary but reasonable minimum threshold of 10 patients waiting in the queue was chosen for the RED model. The drop or redirection rate increases linearly to a maximum of 50% reached at a queue length of 20. It is not unreasonable to assume that staffing levels at each ED do not match demand. Because arrival rates are uniform among the simulated EDs, to make the simulation interesting, two EDs are staffed with 2 doctors, two EDs have 3 doctors, and two EDs have 4 doctors on staff during the simulation.

As in the previous section, three 24 hour scenarios were investigated with ten trials each, and a warm up time of 24 hours. For comparison, the first scenario, which we call No Redirection, assumes that there is no ED status information available and that patients are better off going to the nearest ED and remaining there no matter what the wait. The second is the mode where redirection occurs based on the discussed RED model, and the destination ED is chosen from a uniform probability, we refer to this as Random RED. The third is the form of RED redirection where EDs with lower expected waiting time are probabilistically chosen more often as the destination ED. We refer to this case as Guided RED.

Un-aggregated patient wait times are not shown for these scenarios. The reason is because of the disparity between ED conditions, patient wait times vary wildly. However,

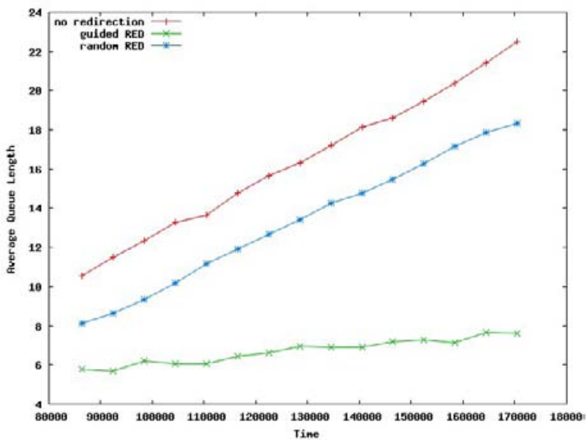

Fig. 9. Average Queue Lengths for Various Redirection Policies

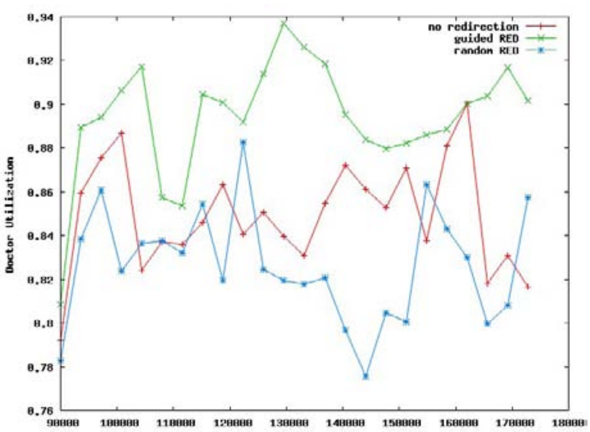

Fig. 10. Average Doctor Utilization for Various Redirection Policies

we can see from Figure 9 that average queue lengths among all hospitals are shortest for Guided RED. Also, in Figure 10 overall doctor utilization is highest in the Guided RED scenario. The improved doctor utilization results in significantly reduced queue lengths or equivalently reduced patient waiting times. It is interesting to note that a significant queue length reduction (waiting time) was achieved with only a modest increase in utilization and no additional resources.

5 Summary

This concept paper presented an agent based modeling system oriented to the simulation of emergency departments in either stand alone mode, multiple interacting emergency departments, as well as technologies well suited to enhance simulation with statistical empirical data collected in real time. Ideas from Telecommunications Engineering are introduced as a model for policy change regarding patient redirection. Simulation alone is not sufficient due to the difficulty in predicting highly uncertain patient arrival rates whereas the system presented here is oriented to augmenting simulation with empirical data when available. As such, the context of the work here also presented a means where emerging technologies such as RFID are suggested as data sources. These sources can be mined in a statistically significant manner and provide real world input for the simulation. The system we are developing is also open source and relies on open source components. It is extendable and can be ported or tailored to a variety of hospital IT applications several of which were identified here.

Acknowledgments. Many thanks go to individuals who have contributed to the platform presented here. These people include Professors B. McLeod and A. Alfa from the University of Manitoba. In addition, we acknowledge the collaboration with Mr. D. Sanders and Mr. B. Podaima from the Internet Innovation Centre, also at the University of Manitoba.

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Weird Project: E-Health Service Improvement Using WiMAX

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Abstract. Today the major obstacle to massive deployment of telemedicine applications are the security issues related to the exchange of real time information between different elements that are not at fixed locations. WiMAX, the new standard for wireless communications, is one of the most promising technologies for broadband access in a fixed and mobile environment and it is expected to overcome the above mentioned obstacle. The FP6-WEIRD [1] (WiMax Extension to Isolated Remote Data networks) project has: analysed how this technology can guarantee secure real time data transmission between mobile elements, built some successful demonstrations and paved the way to future commercial applications. This paper in particular describes: main promising e-health applications that WiMax would enable; the technological highlights and the main challenges that WiMax has to face in e-health applications such as accounting, privacy, security, data integrity; the way in which the WEIRD project 0 has studied the wireless access to medical communities and equipment in remote or impervious areas. 0 0; some envisaged implementations.

1 Introduction

Today the major limit to the deployment of telemedicine applications consists in the impossibility to exchange secure real time information between different elements that are not at fixed locations. Examples of advanced medical services that wireless data and images transmission would make it possible are:

- **Remote follow-up:** to avoid travels that patients are obliged to undertake today in order to reach far-away hospitals to be followed-up after therapies or chirurgical interventions.
- **Remote diagnosis:** to fulfil the need to transmit urgent data in order to make an immediate basic diagnosis, e.g., in occasion of street accidents, for people in special health conditions such as peace-maker bearers, pregnant women, etc. Two sub cases are envisaged: Data are collected in a fix place; Data are collected on a moving medium, e.g. an ambulance.

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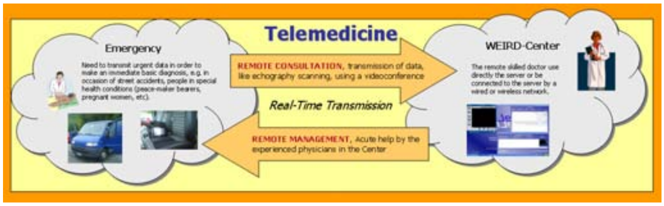

Fig. 1. WEIRD project European telemedicine application

- **Needs to intervene on non transportable patients** (e.g. accidents, childbirth at home): These cases may require off-air transmission of critical data or images (e.g. last echography, PET, real-time video).
- **Remote monitoring:** today elder people are remotely monitored only when at home, but not when travelling or simply walking in town or sitting in a park; remote monitoring will allow this too.
- **Remote assistance:** patients dismissed by hospitals often need to be reminded about therapies and medicines wherever they are (alarms, easy instructions).
- **Medical e-learning:** in order to allow doctors and caretakers to receive news, be trained, or just receive basic or advanced information directly to their premises or when travelling.

Today the use of these services is very limited, the main applications being in the educational field. Their take-off depends on the availability of the necessary wireless broadband access at acceptable costs and at acceptable security.

2 Service Framework

Hereafter few scenarios are described where the above mentioned services are offered to patients by using advanced transmission techniques, with the objective to identify the technical requirements that telemedicine sets to telecommunications.

Remote Follow-up

Patients affected by rare diseases or diseases for which highly expensive equipment are needed are treated in highly specialized medical structures and monitored once released.

Monitoring implies the periodic collection of medical data and images (echographies, ECG holter, spirometry holter, etc.) by a remote operator (in most cases the General Practitioner) and subsequent transmission to the specialized centre. Such data collection can take place either at a general practitioner consulting room or at patient's home.

The GP (General Practitioner) operator is equipped with portable equipment, such as ultrasound or ECG, and traditional tools, such as thermometer, stethoscope and digital pressure meter. He takes measures and images and transmits them to the specialized centre, adding verbal comments on patient's appearance or any other useful information.

Fig. 2. Remote follow up: ECG exam in GP study

Remote Diagnosis

Remote Diagnosis is extremely useful when urgent interventions are to be prepared in the surgery of a hospital or specialized centre, e.g. in case a surgery has to be prepared to intervene on injured people or to cope with an urgent child delivery. The on-field operator is equipped with portable ultrasound equipment and traditional meters. Collection and transmission are as in the previous case (Remote follow-up). The wireless network must hold the session during roaming in the case that data are collected on a moving medium (e.g. an ambulance).

Today it is possible to perform basic remote diagnosis on ambulances which transmit data to their reference centres using satellite transmission and expensive end-user equipment: this prevents a broad adoption of these kinds of services.

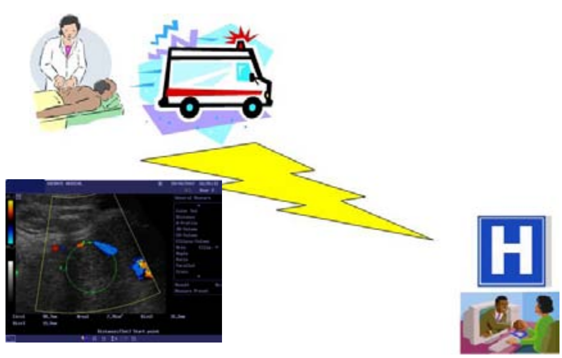

Fig. 3. Remote Diagnosis: examination taken during the travel to the hospital

Remote diagnosis in far-away and scarcely populated Areas

A different application of remote diagnosis is expected to expand rapidly in remote and scarcely populated areas (e.g. valleys on the Alps) where family doctors have to play broader roles and cannot send their patients to specialized centres as easily as in towns. In most of these cases the information exchange does not have real-time requirements, but the absence of wired broadband infrastructures may call for WiMAX capabilities.

Needs to intervene on non transportable patients

The need may arise either in urgency (e.g. an accident, a sudden disease) or not (e.g. a pregnant lady who decides to deliver at home). In both cases the on-field operator (the GP or first aid operator) may need the second opinion of an expert who can either be fixed (e.g. in hospital) or moving (e.g. travelling, on holidays). There can be the need for a technical discussion around an image simultaneously available at both ends. Even more, opening a videoconference session, the field operator has the possibility to show to the remote expert the data he is collecting (e.g. the moving echographic images), to ask for opinion and be followed while acting. This requires available bandwidth in the order of several Mb/s, VoIP and session holding when roaming.

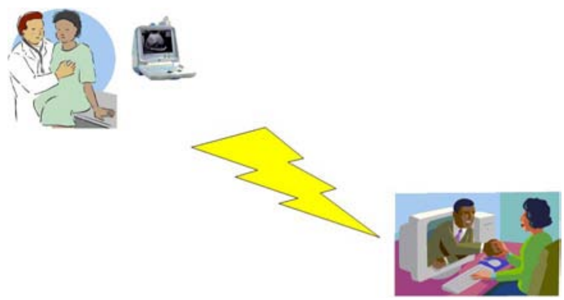

Fig. 4. Non transportable patient: caregiver at patient home supported by remote doctor

Remote Monitoring

Some people need to be full time real-time monitored (24 x 365) even if not hospitalized. These persons are equipped with an always-on equipment able to capture sounds, images and to perform simple measures (e.g., cardiac pulse). Collected information is transmitted to an operating centre In case something abnormal is evidenced, an operator gets in touch with the medical mobile centre nearest to the patient asking for intervention. This requires voice, video, and data transmission over the wireless network.

Remote assistance

This is a narrowband application consisting in sending alarms whenever the patient has to be reminded of making an exam or taking a medicine. Furthermore, the expert, that

Fig. 5. Remote assistance: patient are reachable wherever they are

should be a doctor or another social assistant, should be easily reachable and able to support the patient at home with real-time or almost real-time opinions and instructions.

Medical E-learning

This is a standard e-learning platform that includes basic and advanced training courses and information for doctors. The most frequently asked questions and answers and other services that may improve the quality of the first medical service and reduce costs.

Fig. 6. Medical e-learning: expertise sharing

From a network requirements standpoint, the above services can be grouped in two classes: services requiring network session holding when roaming and services not requiring this feature. The following table summarizes the bandwidth wideness and service components that e-health applications require. It can be seen that all such requirements are expected to be fulfilled by the forthcoming WiMax technology.

Application	Patient data transfer	Patient medical images transfer	Patient medical streaming transfer	VoIp call	Video Conference
Bandwidth requirements	**64** Kbps	**128** Kbps	**512** Kbps	**64** Kbps	**256/512** kbps

3 Equipment and Network Evolution

Equipment wise, users can be assumed to have always portable end-user medical equipment. The progresses in both miniaturized technology and batteries let envisage that, in a near future, every-day-used portable medical devices will be equipped with wireless access (Wifi, UMTS, WiMax) in the same way smart phones are equipped today.

PC based ultrasounds able to collect echographic images and send it to a wireless network already exist, but their use is very seldom and limited to specific applications. Today these devices are used mainly for ergonomic reasons (are light and small) but they are hardly accepted by the medical operators. It is expected that the new generation of medical operators will show a different behaviour and overcome this psychological barrier. Furthermore the today geographically limited availability of broadband accesses will be overcome by WiMax.

4 Privacy and Data Integrity

Telemedicine deals with sensible personal data, therefore issues such as privacy, integrity, authentication, authorization are crucial in determining its viability. Data (including images) transmission for monitoring and diagnosis purposes must be authorized, authenticated and may be required to remain anonymous to some level of operators along the chain. Data storage is to be guaranteed for medical record tracking purposes. Data integrity needs to be guaranteed during manipulations and storing to avoid the risk of wrong prognosis caused by incomplete or mixed-up information. In urgent applications time is critical: to assure data transmission in real time priority has to be granted.

Designed by the IEEE 802.16 committee, WiMAX was developed after the security failures of early IEEE 802.11 networks. The 802.16 working groups designed several mechanisms to protect the service provider from theft of service, and to protect the customer from unauthorized information disclosure. A fundamental principle in these networks is that each subscriber station (SS) must have a X.509 certificate that will uniquely identify the subscriber. The use of X.509 certificates makes it difficult for an attacker to spoof the identity of legitimate subscribers, providing ample protection against theft of service and the 802.16e amendment added support for the Extensible Authentication Protocol (EAP) to WiMAX networks. Support for EAP protocols is currently optional for service providers. Also with the 802.16e amendment, support for the AES cipher is available, providing strong support for confidentiality of data traffic. Like the 802.11 specification, management frames are not encrypted, allowing an attacker to collect information about subscribers in the area and other potentially sensitive network characteristics.

5 Telecommunication Technology

The WEIRD project aims to exploit and enhance the WiMAX technology in a convergence layer heterogeneous network architecture, in order to cope with future needs of research user communities and to build testbeds allowing the European research backbone networks like GÈANT, GÈANT2 0 and relevant National Research and Education Networks (NRENs), to be reachable from isolated or remote areas. To build such a broadband access network infrastructure, and to improve the QoS and user experience, the WEIRD project workplan included the following technical challenges:

- Enhancements to the WiMAX technology
  - QoS support
  - Interoperability with mobility management 0 0
  - Radio-over-Fiber (RoF) techniques

- Enhancements to the IP network Control Plane
  - Advanced AAA
  - QoS support for real time critical applications,
  - Resource management to control bandwidth allocation
  - Roaming mechanism for connections of nomadic researcher stations to GÈANT
- Supporting studies and deployment recommendations
  - Simulations
  - Network planning,
  - Device configurations
  - Guidelines and best-practices for the permanent deployment of the WEIRD architecture in GÈANT and NRENs
  - Liaisons and project feedback with all sponsoring research organisations (GARR, ROEDUNET, RED.ES, FUNET).
- Liaisons with all projects relevant to WEIRD and progressing in FP6 and EUREKA programs.

6 Weird Applications Scenario

The scientific user communities that have participated into the project are the Fire Prevention Laboratory of University of Coimbra – Portugal, the Association OASI Maria SS - Italy, the Osservatiorio Vesuviano Volcano monitoring scientific site Italy and the Icelandic Meteorological office - Iceland. These communities have described their user scenarios that will drive the specification of system requirements and subsequent specifications.

The main scenarios in which the WEIRD system shall be able to operate are:

- WiMAX as a wireless access infrastructure for research networks in remote areas
- Broadband access for fixed remote research sites where wired solutions are not cost-effective
- Broadband mobile access for nomadic personnel and aggregation systems collecting data from sensor equipments in impervious areas (e.g., volcano)
- Broadband mobile access for fire monitoring and prevention
- Broadband mobile access for medical personnel requiring high resolution medical information in nomadic emergency situation
- Broadband mobile access for high resolution tele-hospitalization.

The technical solutions developed within the WEIRD project have been implemented, tested and validated in four testbeds deployed in Europe. The testbeds are located in Finland, Italy, Portugal and Romania, and the interconnection between testbeds is based on the pan-European GEANT2 research network (Figure 7).

The testbeds have different profiles and technology according to the aforementioned scenarios. Moreover, every testbed is specialized in order to highlight certain technical solutions. Thus, the WEIRD Project moves in a considerably large and rich domain for validating the developed solutions. This is considered as one of the most valuable and unique assets of the project. Even though not all of the application scenarios and technical enhancements are developed in every testbed, the project aims to provide the

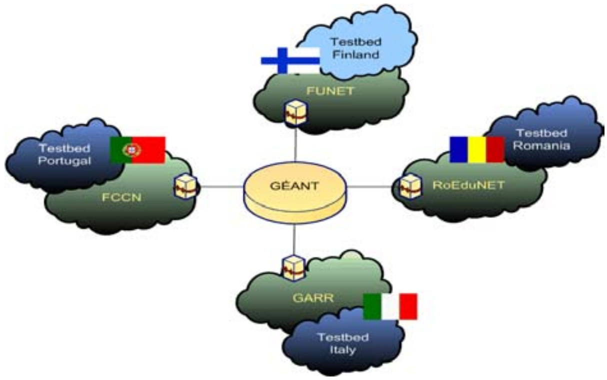

Fig. 7. WEIRD project European testbeds interconnection through GEANT research network

developed solutions for each testbed at the end of the project and to demonstrate some interworking of the selected applications in larger scale e.g. the Video over IP and VoIP transmission through the pan-European research network. The WEIRD architecture 0 has been designed to seamlessly integrate and support all the mentioned applications, including e-health. To achieve this aim, an API (WEIRD API) has been specified and implemented on the client side of the network. This API provides an interface between the e-health application and the QoS signaling protocol that has been chosen for the project – IETF NSIS 0. For the integration of the e-health application with the WEIRD API, it has been necessary to modify and adapt the application, allowing the required QoS parameters to be conveyed to the NSIS protocol. NSIS forwards the received QoS information to the network side QoS management entity, and the later will perform the resources allocation on the WiMAX link. This process guarantees that e-health applications will have the required bandwidth allocated on the WiMAX link in order to have a good performance without traffic disruption.

7 E-Health Demo Scenarios

Today the major E-health is one of the application areas more benefiting from WiMax Technology. The main object of telemedicine is to allow people in remote sites to exchange patient data, diagnostic images and video streaming generated by medical devices without any quality loss during the transmission. The required bandwidth depends on the application and should be increased or decreased on demand. In order to support emergency applications the data exchange should be done in fixed place as well as travelling. E-health applications can use voice and video over IP in order to support real-time communications in case of emergency. In addition, the same applications could support services such as remote assistance and patient's monitoring as well as distribution and collection of data. Scalable Collaborative platforms with web interfaces could be deployed by the medical authorities and easy administrated. As a result of the above presented scenarios, e-health applications represent excellent drivers for both broadband and mobility requirements. The need to have an always-on broadband link between the ambulance and the serving hospital is a strong requirement for both WiMAX and

3G-HDSPA/LTE architectures. The channel availability is an issue that cannot be solved with traditional 3G/GPRS deployment. WEIRD project has also analysed 0 0 the potential market for such telemedicine applications and drivers on based on the analysis made available by the WiMAX Forum (Figure 8).

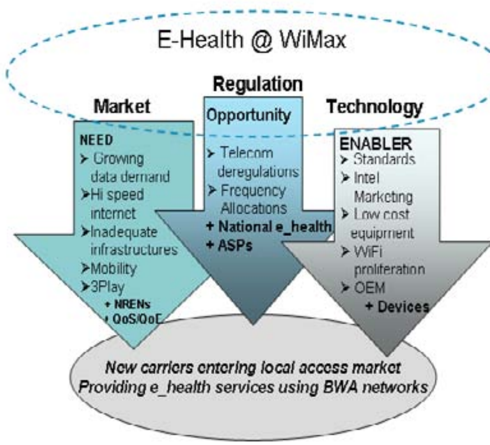

Fig. 8. WEIRD E-Health Market Drivers

Improving the efficiency of internal processes is one of the key business issues in the health and social sectors. Whereas the basic technical telecommunications and public infrastructure, including physical networks, generic interoperable services and adequate security, are in place in most Member States 0, a crucial layer comprising servers and services (ASPs) for sharing (regulation) both patient clinical and back-office information and thereby providing the missing connectivity is largely lacking, as is the upper layer of e-commerce applications to support patient care processes, the management of facilities and the (quality) control of health systems and thereby may be expected to become the economic drivers for e-business diffusion 0.

Another aspect is that the sector is a highly regulated national, often even regional market. Trends such as the expansion of private hospital chains and other private actors entering the market may change this over the years to come. Figure 8, shows and decouples market drivers for e-health applications using WiMAX technologies. On top of existing analysis of WiMAX Forum, new elements (+) have been added for the market, regulations and technologies.

8 Conclusion

Today the major Broadband Access Technologies like WiMAX are enabling factors for e-health solutions. WiMAX can yield additional benefits in term of availability of broadband communication channels, QoS, interworking with convergent networks and mobility of the subscribers.

Today a large number of activities are carried out with limited success, unnecessary costs and human difficulties because of the impossibility to exchange real time information between different elements of the chain that are not at fixed locations. The massive commercial availability of WiMax technology and WiMax based services will make these activities cost-effective and successful paving the way to the realization of an e-health environment. Here following are reported some real cases of today, costly and therefore limited applications, that the availability of WiMax will make cost-effective thus opening new opportunities for business and social development:

– Oasi is a Sicilian clinical research institute active in the field of mental disease. This institute provides diagnosis, care and rehabilitation for its patients when at home after hospitalization other than training and support to caregivers and patients' relatives. Today this implies a large number of travels to both patients and caregivers from/to hospital. Oasi is waiting for WiMax large scale availability both to avoid these unnecessary travels and related costs and to improve services and features.

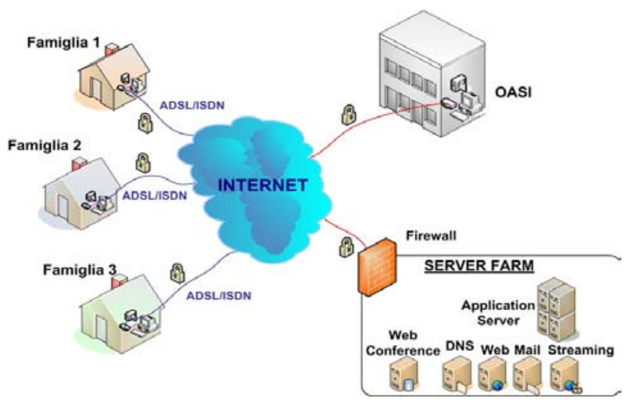

Fig. 9. OASIweb architecture

– SIMG is the most active organization of General Practitioners in Italy and plans to implement a web-based e-learning system with the objective to distribute to its associates new scientific and technology findings, thus keeping them constantly updated, organise courses on basic use of ultrasound systems as first opinion, and give full time on-line support. The present obstacle to the implementation of such business model is constituted by the mobility characteristics of GPs. A WiMax-based solution is under study to overcome this blocking factor.
– There are several similar cases of remote diagnosis in isolated far-away areas such as in Latin-America. An example is represented by the management of the so called Tele-salud centres which provide first level care in remote areas such as Amazonia and Andes. Today the clinical reporting and second opinion are provided using expensive and low efficient radio and satellite connections. WiMax will highly improve both operational costs and efficiency.

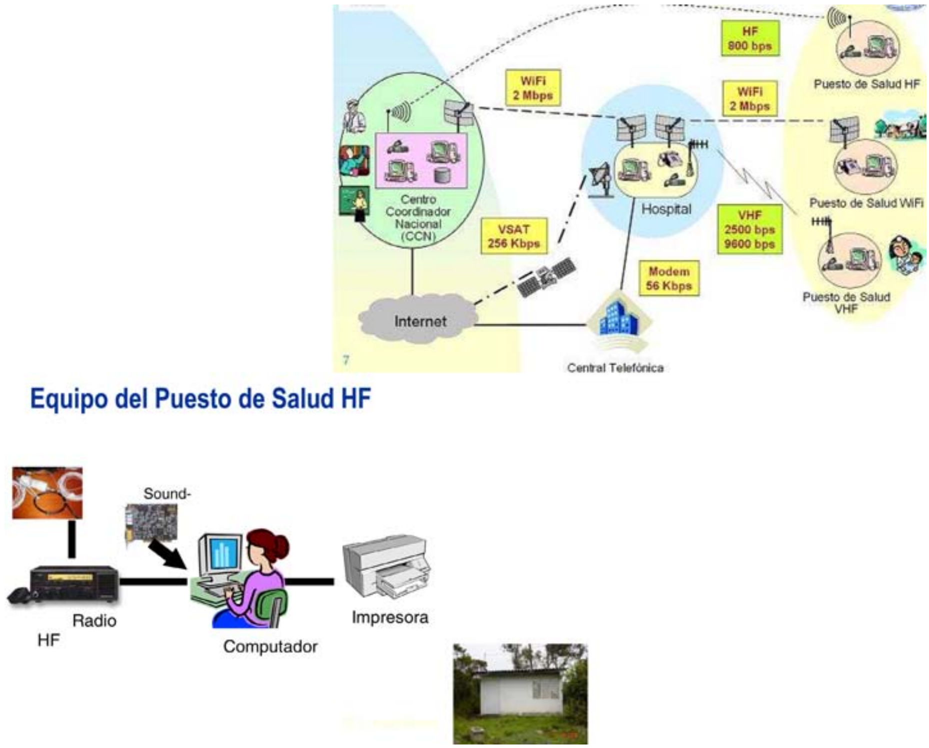

Fig. 10. Telesalud network and remote site

The Project FP6_WEIRD have studied these business models for social applications such as telemedicine and environmental monitoring (fire prevention, volcano monitoring) and the business case results are almost the same: R&D organizations have developed the needed technologies that industry is ready to bring into products and make available on large scale. The public sector is expected to trigger the process thus representing one of the major drivers for broadband mobile technologies.

Acknowledgements. This work is partially supported by European Project WEIRD (IST-034622-IP). Authors thank the partners of the WEIRD consortium for their valuable help.

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21. TELE-SALUD

Data Management in an Intelligent Environment for Cognitive Disabled and Elderly People

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Abstract. Recently intelligent and personalized medical systems tend to be one of the most important branches of the health-care domain, playing a great role in improving the quality of life of people that want to feel safe and to be assisted not regarding the place they are. This paper presents an innovative way of data management based on a middleware platform providing services for fast and easy creation of applications dealing with the problems of taking care of patients in their homes. The work was carried out as a part of the MPOWER project, funded by the EU 6th Framework Programme, and carried out by a multinational development team. The project focuses on supporting activities of daily living and provides services for elderly and cognitive disabled, e.g. people with dementia. The MPOWER platform is designed to facilitate rapid development of a variety of applications and adopt them to specific users' needs. The paper introduces the whole platform, its functionality and principal goals along with the architectural background of data management, focusing on the different types of data that the system has to manage and analyze. The last section concludes the work done on the project.

1 Introduction

Nowadays taking care of elderly people using modern technologies is one of the general objectives of health-care domain research companies. This paper is based on one of those recent investigation projects – namely the MPOWER project. The project seeks to find solutions for cognitive disabled and elderly people to make their life more independent and to improve their life quality standard. Thus, MPOWER joins the most important health-care solutions for remote assistance, social-health care and surveillance**.** Moreover, MPOWER helps in managing the medical information and also possesses management solutions for networks of domotic (sensors) and medical devices which are considered as an important factor in making the life of the elderly independent. The MPOWER middleware is targeted to developers in order simplify and speed up the development process of applications for elderly and cognitive disabled persons.

With the open platform of MPOWER, developers are allowed to create and integrate new services as also they dispose a set of basic and complex ready made

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services in the platform, e.g., services for: information management including social and medical information, different communication channels with monitoring functionality, interoperability between different specific medical systems, security of information management, and at the end SMART HOUSE and sensor related services. The last ones together with the communication services create a mechanism which serves to monitor and control remotely the patient environment and allow reacting in a certain way in particular situations. Within the platform there is an integration component that supports different types of sensors. Components for processing the data captured from aforementioned sensors as well as mechanisms for data analysis is also developed. The MPOWER project deals with different types of data, defines the internal data-flow and finally provides services which make use of the analyzed information and manipulates with the provided data. All these services along with services to manage actuators and communication services such as video conferencing, mobile or email notifications form a mechanism that can make the life of the elderly safer and more independent. For example people with dementia can be given constant support not only in case of emergency situations but also in their activities of daily living.

2 Project Principal Objectives

The main objective of the MPOWER project is to create a platform of reusable, flexible, interoperable and innovative social and health-care related services. This platform makes possible rapid and easy development of novel smart-home sensor applications which help to take care and empower the everyday's live of elderly people in their daily activities. In this way cognitively disabled people will be more assisted and then they should feel more secure at their homes [3]. Within the project two proof of concept applications are being developed: one with the goal of demonstrating the feasibility of the platform with information sharing functionality and another that presents the usage of MPOWER platform with sensor's network and smart home technologies. Sensor networks together with the different communication and remote monitoring solutions may increase the level of patient's security and assistance by various mechanisms of control. In such way patients of different characteristics or the elderly can stay at constant surveillance by medical and care giving personnel.

The second objective of the project is applying new trends in software development process and architecture, in this case making use of Model-Driven Software Development for Service Oriented Architecture [2]. There has been worked out its proper toolchain for services creation based on UML models. These models are later transformed and some code is automatically generated.

3 Platform Functionality

This section gives an overview of the functionality provided by MPOWER. These functionalities, many of them implemented as web services make use of the data received from the MPOWER environment providing the data analysis and finally help

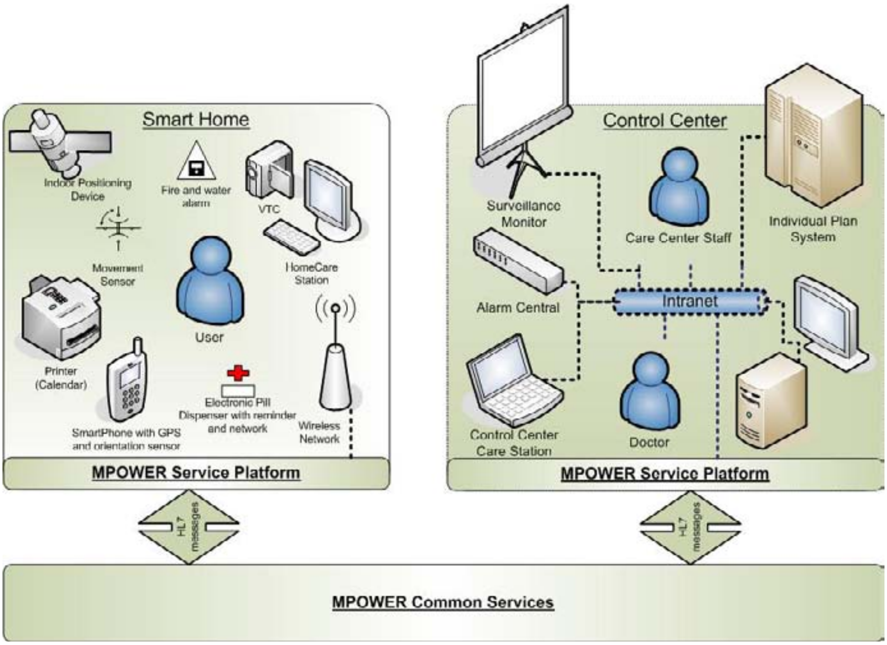

Fig. 1. MPOWER platform elements

the medical personnel or caregivers to take care of the subject of care and have them under constant attention providing constant assistance.

Moreover MPOWER-based systems consist of two parts: one intended for the subject of care (patients), and one designed for the healthcare personnel and caregivers. Figure 1 presents an example of a MPOWER application as care center and smart house environments. These two parts communicate with each other through different middleware services or directly passing medical information. Some services use HL7 format others not depending on the message origin. HL7 messages play an important role when exchanging information with legacy systems or other health systems. In the smart house environment a very important factor is the data capturing and its manipulation. Different types of devices or sensors send the data and MPOWER has to be able to read and interpret the data. For this purpose MPOWER provides special components that facilitate the data manipulation process describing the proper data flow.

For example, patients’ movements can be controlled through a tracking system which sends information about the current patient position to a control point. Two services have been implemented to provide this functionality, monitoring indoor and outdoor location of the elderly. Patients can be easily localized in the case of different situations. GPS and WiFi technologies let caregivers and even family members be aware of this fact and help them is such case.

Another feature of the platform provided for the elderly is giving the possibility of sending alarm information in situations when the patient feels insecure or needs urgent medical assistance. This functionality is covered by a notification mechanism designed as another basic and crucial platform service. In this situation caregivers can communicate with the MPOWER application user through different communication channels depending on its current location. For this purpose audio and audio-video conferencing as well as surveillance cameras services are provided to have the full control and contact with the patient at any time.

Medical and social information is also managed by the MPOWER services. Medical information can be exchanged with other medical systems using HL7v3 messages standards. Subjects of care and care centers can communicate also through messaging services which play the role of reminders, passing different medial data or just simple notification messages.

MPOWER services can be used separately or in cooperation with other services. The platform has been designed in such a way that use of services can be orchestrated through designing business processes and running them on an integration platform such as Enterprise Service Bus (ESB) where processes and data flows can be defined through implementing appropriate BPEL for each situation treatment.

4 Data Management Mechanisms

Cases where MPOWER solutions are applied often involves analysis and management of data collected from different sources. This data is provided to the middleware services by a specially prepared component called Frame Sensor Adaptor (FSA) which unifies the way of data capturing for either medical devices or different kind of sensors and Smart Home standards (in the case of MPOWER proof of concept domotic sensors were used) or any other kind of incoming data.

Data received through the FSA is passed (through Enterprise Service Bus - ESB) to another component called ContextManager where the data is analyzed. This analysis is based on rules defined in the platform environment. Rules matching can detect the emergency situations and react in a particular manner e.g. an alarm notification can be sent to a mobile phone or to another platform service.

Figure 2 presents a data flow diagram from the data capturing stage to the final notifications sending. As showed on the diagram the central element of the data management mechanism is the Enterprise Service Bus (ESB) which gathers all collected data and passes it to the appropriate targets. The main element which analyzes the data is the ContextManager component which performs expected data analysis.

4.1 Frame Sensor Adapter (FSA)

The MPOWER platform is prepared to receive information from any known medical device, network of sensors or incoming source. Ambient Assisted Living is one of the most important factors when providing a remote assistance and monitoring of the elderly. There has been created a component called FSA [4] thanks to which any sensor/actuator or device can be integrated with the MPOWER environment. That is the most important feature of the component. FSA serves to receive data from those devices and send them to a predefined target in a specific format. FSA receives heterogeneous information from many kind of devices and transforms it to a

Fig. 2. MPOWER environment data flow

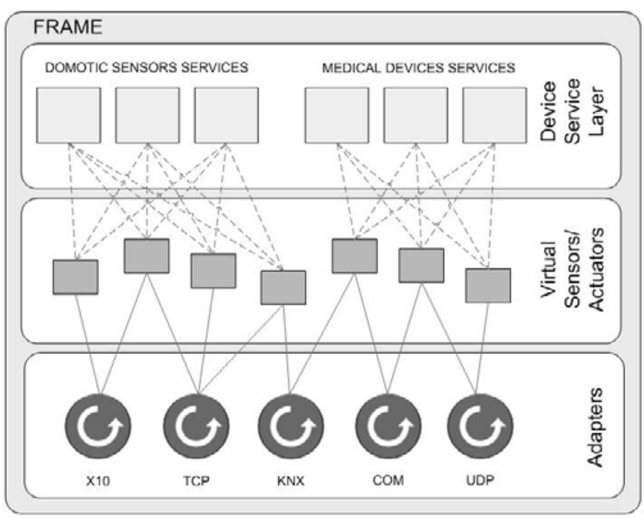

Fig. 3. Frame Sensor Adapter architecture

standardized messages using IEEE 11073 specification. This message is later sent to the aforementioned integration environment ESB. Any component or service which is designed to make use of this data has to subscribe to this bus in order to capture the data in the time of its inserting to the messaging bus.

FSA architecture defines a framework to access sensors and actuators through several communication channels with the same interface in terms of information instead of raw data and whatever the information comes from. The goal of the FSA model is to hide complexity and details inherent to the sensor communication to the remaining system. The FSA model can be divided into three layers: Adapters, Virtual Sensors/Actuators and Device Services. In terms of SOA, the first two aforementioned layers belong to resource layer, whereas the last one - Device Services belongs to the service layer.

Adapters face communication protocols and can communicate with the physical layer (devices, sensors). For instance, serial port adapter knows which virtual sensor it is associated with, so when a message from real sensor comes, the protocol specific adapter figures out related the virtual sensor. Then the message is passed to that virtual sensor which knows which message format to be used for communication with a physical sensor and which represent a device/sensor in the system.

Furthermore, there exists another layer which makes the captured data accessible for any external component. This layer consists of web services which talk to the proper virtual sensor asking for specific information.

4.2 Context Management

The component called ContextManager allows taking certain actions suitable for the given context where context is defined as a particular state of environment where the platform is running. It is an important piece of software which compares the received data produced by domotic sensors or medical devices with predefined by the user situations to be recognized and treated. These situations (contexts) are described by a series of rules and the execution of the comparison is done by a rules engine [6]. This mechanism responds differently when a particular rule matches the given at the moment context. Its main objective is to launch specific alarm types related to different kind of those situations. Afterwards other components or services are able to receive the alarm notifications and react properly. Figure 4 presents the MPOWER architecture emphasizing the FSA, ContextManager and ESB roles. The arrows represent the data flow within the MPOWER environment.

4.3 Enterprise Service Bus - ESB

The ESB plays a crucial and very strategic role in controlling the MPOWER data flow. It gathers all the information from the physical level and distributes it to the proper target. Moreover by the means of different kind of binding components and service engines ESB can manage with a variety of protocols and messages formats as SOAP or JMS.

MPOWER is designed to use business processes definitions in Business Process Execution Language (BPEL). For example there exists a process especially prepared to control the data flow during the notification process execution which runs on the BPEL integrated engine. The notification process serves to send the alarm notification messages to the subscribed applications and control its treatment progress. The chosen ESB environment for the project was Open-ESB [5].

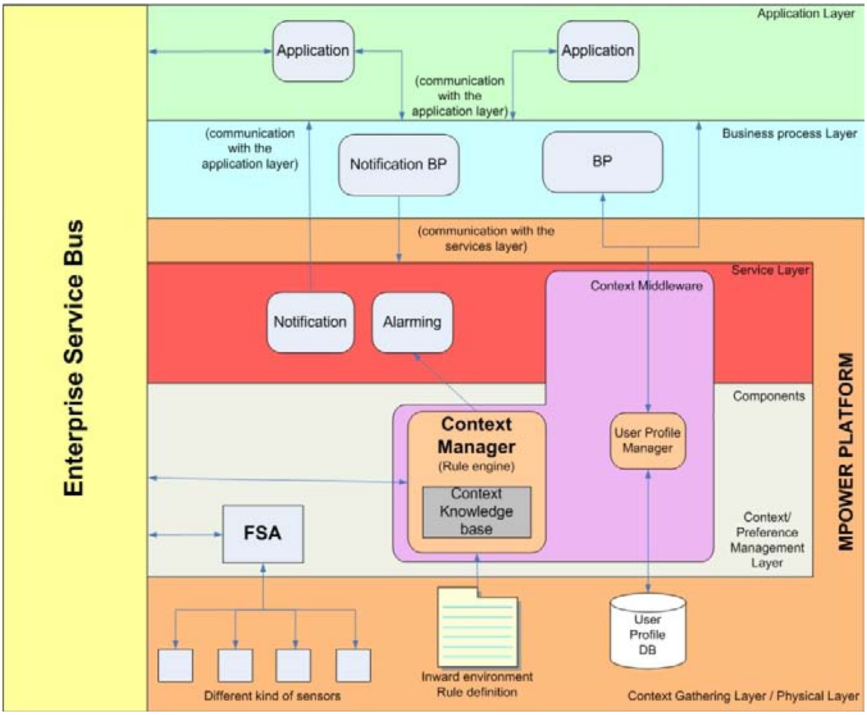

Fig. 4. Context Manager within the MPOWER architecture

5 Conclusions

Many people need medical assistance, but it is very hard for them to accept the new conditions of living in residences, clinics or other medical centers. Therefore new trends are to assure the constant medical support, patients surveillance and assistance, in the place of their living. In case of the MPOWER project the target group of end users is elderly and cognitive disabled. The elderly can stay at their houses sending necessary medical data to their medical centers and being constantly monitored or attended to raise their independence and to improve their quality of life.

The MPOWER project now reaches its final stage of development. Within the project has been created a platform for the development of interoperable applications that use innovative end-user services. Key application-level and integrated complex services have been implemented. In order to validate the MPOWER middleware platform two Proof-of-concept applications were designed for end-users of different needs and characteristics. The main achievement is providing two applications: first that help in medical information sharing and the second one which is SMART HOUSE technologies based. Both applications are currently being tested in order to get the feedback from the elderly on how the applications improve their daily life applying new trends in health-care outside their medical centers.

The real platform usage evaluation will be based on that aforementioned feedback. It is expected that MPOWER information, interoperability, security, communication, sensor and SMART HOUSE integration middleware makes the development of health-care applications and integrating new health-care related services fast and easy. Experience gained when developing the platform should be a considerable step towards the sought improvement of life of the elderly and cognitive disabled. It can also indicate new trends of home-care in conjunction with the intelligent environments of sensor technologies.

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3P: Personalized Pregnancy Prediction in IVF Treatment Process

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Abstract. We present an intelligent learning system for improving pregnancy success rate of IVF treatment. Our proposed model uses an SVM based classification system for training a model from past data and making predictions on implantation outcome of new embryos. This study employs an embryo-centered approach. Each embryo is represented with a data feature vector including 17 features related to patient characteristics, clinical diagnosis, treatment method and embryo morphological parameters. Our experimental results demonstrate a prediction accuracy of 82.7%. We have obtained the IVF dataset from Bahceci Women Health, Care Centre, in Istanbul, Turkey.

Keywords: In-vitro fertilization, Embryo implantation prediction, Classification, Support vector machines.

1 Introduction

Infertility is defined as couple's biological inability to conceive pregnancy after at least 12 months of regular, well-timed sexual intercourse without contraception. In-vitro fertilization (IVF) [1] is a process during which female germ cells (oocytes) are inseminated by sperm under laboratory conditions. After 1992 the IVF process is combined with intra-cytoplasmic sperm injection (ICSI) method [2] during which a single sperm cell is injected into the cytoplasm of the oocyte. Fertilized oocytes are cultured between 2-6 days under laboratory conditions during which embryonic growth is observed and selected embryos are transferred into the woman's womb. Selection of embryos with highest implantation (i.e. attachment of the embryo to the inner layer of the womb) potential is crucial for achieving a successful pregnancy.

There are various embryo and patient characteristics which may affect the outcome of an IVF cycle. The conventional and most common way of selecting high quality embryos is to inspect their morphologies. However, non-automated analysis of various patient and embryo parameters is a challenge. The main objective of this study is analyzing the underlying factors of embryo implantation and thus to provide a prediction model. To accomplish this, we propose an intelligent system that uses machine learning methods. These methods use available data for learning and establishing a prediction model.

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1.1 Machine Learning Methods in IVF Data Analysis

Existing studies on IVF data analysis heavily focus on statistical relationships between clinical variables and pregnancy results [3][4]. These studies evaluate the most important predictors for the pregnancy outcome or predict implantation rate depending on limited number of embryo related features. Identification of correlations between input IVF data and pregnancy outcome provide a knowledge base, but selection of embryos with highest implantation potential still depends on decision of embryologists, which may vary from one to another. Therefore, intelligent learning systems can be more suitable to assist embryologists in making the right decision. The machine learning methods are used in medicine for providing decision support on diagnosis and treatment process.

IVF treatment is a complex and costly process requiring decision support and future predictions in certain stages. Because of the difficulty faced in manual observation of multiple variables and examination of nonlinear correlations between features, IVF process requires more advanced prediction models. A machine learning system can automatically analyze large IVF databases to train a model and provide future predictions. Such a system would speed up the embryo selection process and possibly improve the number of successful pregnancies.

On the contrary to the importance and emergence of intelligent decision support systems in IVF process, the related literature is limited. As a preliminary study, Jurisica et. al. represent a case-based reasoning system that exploits past experiences to suggest possible modifications to an IVF treatment plan [5]. Later, a decision tree model is applied to express relationships of features characterizing the “take of baby” and “no-take of baby” classes of embryo batches [6]. Decision trees again used for prediction of pregnancy outcome from clinical IVF data with an accuracy of 67.4% [7]. Trimarchi et. al. build decision tree and logistic regression models and reported 75% and 74% accuracy rates respectively [8]. Another research considers automated recognition of embryos suitable for transfer and compare the recognition of experts with that of a machine programme [9]. The most recent study on implantation prediction proposes a Bayesian classification system for embryo selection and reported an accuracy of 71.4% [10].

Existing approaches generally consider transfer of embryo batches including two or three embryos. However, it is not possible exactly to know which embryo of the batch is implanted. Such an ambiguity decreases the reliability.

1.2 Proposed System for Embryo Implantation Prediction

In IVF pregnancy prediction machine learning methods are constructed as cycle based methods. An IVF cycle consists of controlling the follicular stimulation by external administration of hormones, aspirating oocytes from woman’s ovaries, inseminating the oocytes with sperm cells in vitro, letting them grow in the laboratory and transferring the embryos into the womb. The number of embryos to be transferred varies. The aim of this prediction model is to identify the embryo to implant according to patient and embryo characteristics. Therefore this model could also be useful to minimize high order pregnancies.

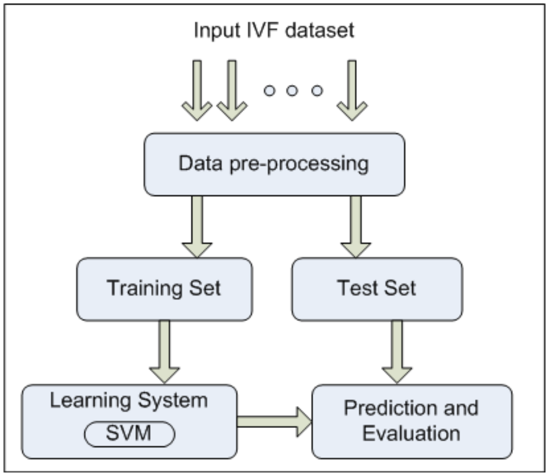

Fig. 1. Schematic representation of proposed learning system for embryo implantation prediction

Cycle based approaches use features of each embryo in a given cycle as a feature vector of all embryos in that cycle. In this case we do not know which embryo got implanted and this causes loss of important information as far as a prediction model is concerned. In this research, we build an embryo based learning system. We classify embryos according to their implantation potentials. In order to avoid the information loss we have only considered clear cases where all of the transferred embryos implanted or not implanted.

The prediction performance of a machine learning based model is based on data and the algorithm to use [14]. In IVF domain, we need to build a model which learns from massive data and comes up with results that can be generalized. Therefore it is important to decide which features to select in order to keep the information content high so that the predictive model returns accurate results. To increase the information content, we chose the most relevant parameters as data features. We used Support Vector Machines (SVM) as the classifier for implantation prediction to learn a model from past IVF data and make predictions on new embryos. The schematic representation of the proposed system can be seen in Fig. 1.

2 Dataset Characteristics

Infertility is a social matter as well as a medical disorder. Because of social and ethical reasons in every country some legislative rules have been defined. Usually, the restrictions apply for donation, embryo manipulation, number of embryos to be transferred in each cycle etc. Besides the legal procedures in countries, every IVF clinic applies different technologies and methodologies in practice. Because of this variety, each clinic has distinctive IVF databases.

In this study, we will analyze the IVF procedure and related database of Bahceci IVF Clinic in Istanbul. The dataset has data on 3000 patients of numerous cycles and embryos collected since 1997. Compared to the ones used in the literature Bahceci dataset uses more numerical values than categorical values and this makes it a more objective dataset to build a prediction model on. We have constructed a dataset from existing database with selected features for certain cases. The proposed classification system is an embryo centered approach and dataset contains a data feature vector for each embryo rather than each cycle. Dataset features and data types are given in Table 1. The features have been selected depending on experiences of senior embryologists in Bahceci IVF Clinic and related studies [11][12][13].

Table 1. Selected dataset features for each embryo feature vector

Dataset Features	**Data Type**
Patient Characteristics	
Woman age	Numerical
Primary or secondary infertility	Categorical
Clinical Diagnosis and Treatment Protocol	
Infertility factor	Categorical
Treatment protocol	Categorical
Duration of stimulation	Numerical
Follicular stimulating hormone dosage	Numerical
Estradiol level	Numerical
Endometrium thickness	Numerical
Sperm quality	Categorical
Embryo Related Data	
Early cleavage morphology	Categorical
Transfer day	Categorical
Number of cells	Categorical
Nucleus characteristic	Categorical
Fragmentation	Categorical
Blastomers	Categorical
Cytoplasm	Categorical
Thickness zona pellucida	Categorical

3 SVM Classification

Support vector machines (SVMs) are a set of related supervised learning methods used for classification and regression. Their common factor is the use of a technique known as the “kernel trick” to apply linear classification techniques to non-linear classification problems.

In classification problem, classifying data as part of a machine-learning process is interesting. When the data points in the set are multidimensional, the classification can be carried out with separating the points by using hyperplanes. This form of classification is linear and the classification is required to be neat with maximum distance to the closest data point from both classes where the distance is the margin [15]. If the hyperplane has this margin property, it is called maximum-margin hyperplane, as are the vectors that are closest to this hyperplane, which are called the support vectors.

Given a set of training data pairs (x_i, y_i), where x_i is the input feature vector and y_i is the class label, the aim of the SVM classifier is to estimate a decision function by constructing the optimal separating hyperplane in the feature space. The key idea of SVM is to map the original input space into a higher dimensional feature space in order to achieve a linear solution. This mapping is done using kernel functions. Final decision function is in the form:

$$f(x) = \left(\sum_i \alpha_i y_i K(x_i \cdot x) + b \right) \tag{1}$$

where $K(x_i \cdot x)$ is the Kernel transformation. The training samples whose Lagrange coefficients α_i are non-zero are called SVs and the decision function is defined by only these vectors.

3.1 Performance Measures

We have used probability of detection (pd) and probability of false alarm (pf) as the performance measures [16]. Formal definitions for these performance criteria are given in Equations 2 and 3 respectively and they are derived from the confusion matrix given in Table 2. *pd* is a measure of accuracy for correctly detecting the embryos that will implant. Therefore, higher *pd*'s are desired. *pf* is a measure for false alarms and desired to have low values.

$$pd = (A)/(A + C) \tag{2}$$

$$pf = (B)/(B + D) \tag{3}$$

$$FN = (C)/(A + C) \tag{4}$$

As a measure of performance false positives (FP) and false negatives (FN) are also used. Since, the *FP* rate is the same as *pf* measure; we additionally consider analysis of *FN* rate in this study. Equation 4 represents the formulation of *FN* rate which is the proportion of implanted embryos that were erroneously reported as not-implanted. *FN* is an error measure for missing the embryos that will implant. So, it is critical to reduce FN rate in prediction results.

Table 2. Confusion Matrix

	Predicted	
Actual Case	Implanted	Not-implanted
Implanted	A	C
Not-implanted	B	D

4 Experiments and Results

The IVF dataset used in this study includes 546 embryo records which have been transferred in day 2 or day 3 and each embryo data vector is represented by 17 feature values (Table 1). There are two classes of embryos, class label 1 indicates implantation and class label 0 indicates no-implantation. The distribution of classes over training and test sets are given in Table 3.

Table 3. Number of implanted and not-implanted embryo samples in training and test sets

Case of classes	Training set	Test set	Total
Implanted	218	55	273
Not-implanted	218	55	273
Total	436	110	546

Experiments have been performed using LIBSVM tool [17] in MATLAB environment. Kernel and model parameter selection is crucial for the performance of SVM classifier. We have tested the classifier with linear, polynomial and Gaussian kernels. Gaussian Kernel has been the choice of kernel because of superior performance with default model parameters. In order to optimize the SVM classifier model with Gaussian kernel, the kernel parameter *gamma* and the model parameter *cost* and are searched in the ranges $\left[2^{-5}, 2^{15}\right]$ and $\left[2^{-15}, 2^{3}\right]$, respectively, using a grid search algorithm. Optimal model parameters and prediction results in terms of defined performance measures are given in Table 4.

Table 4. Optimal model settings for SVM classifier and classification results

Kernel	Kernel parameter	Cost	Accuracy	pd	pf	FN
Gaussian	Gamma = 0.078	32	82.7%	80%	14.5%	20%

Table 5 presents the confusion matrix for classification results. SVM classification for implantation prediction resulted in 82.7% overall accuracy with 80%

Table 5. Confusion matrix for implantation prediction results of SVM classifier

		Predicted Results		
	Case of classes	Implanted	Not-implanted	Error rate (%)
Test Set				
Implanted	55	44	11	20.0
Not-implanted	55	8	47	14.5
Total	110	52	58	17.3

probability of implantation detection and 20% of *FN* rate. The most critical performance measure in embryo selection process is *FN* values. We aim to minimize *FN* rate because we don't want to miss the embryos that will implant.

4.1 Threats to Validity

Compared to similar research in the literature we have used a much larger data set, but, in machine learning standards it may be considered small and hence a threat to validity. However, our previous studies in different domains showed that our models prediction performance is good with as little as 100 samples [16]. The IVF datasets differ in each clinic as explained in Section 2. Hence, direct comparison of results with similar studies is not reliable. This may be a threat to validity as to how reliable and good our empirical results are. However, as to comparing our defect predictors with standard results from the data mining community, in prior work, we have checked the efficacy of data mining on standard machine learning datasets such as UCI repository [18]. On average state of the art data miners perform at (pd,pf) = (81%, 20%). This is close to the results we have obtainedvia data mining on IVF embryo and cycle attributes (pd,pf,FN) = (80%, 14.5%,20%).

5 Conclusions and Future Work

We have defined embryo implantation prediction as a 2-class classification problem and explained its emergence for improving IVF treatment success rate. Our approach is different than the existing ones in the literature that we use embryo based prediction rather than cycle based prediction. Our empirical results show that our proposed model predicts correctly in 82.7% of the time. We have proposed an SVM based learning system and our results showed that a learning based intelligent system can predict pregnancies in a personalized manner at least as good as the most experienced embryologist. Moreover we have seen that our proposed model has *FN* rate which is misclassifying the embryos as no implant is lower than the expert's judgement.

Our future work will be to calibrate our model by using different algorithms to further lower the *FN* rate as well as to enlarge the sample size. We will also work on the selection of features to better understand the correlations among them to better personalize the pregnancy prediction in IVF treatment.

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Bridging the Self-care Deficit Gap: Remote Patient Monitoring and the Hospital-at-Home

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Abstract. This study examines the use of a remote patient monitoring intervention to address the challenge of patient self-care in complex hospital-at-home therapies. It was shown that in a home hemodialysis patient group, remote patient monitoring facilitated self-care and was supported by patients and, in particular, family caregivers. This does not come without cost to the patient however, who now has greater personal responsibility and accountability for their health management. Promising results from this study indicate that most patients are willing to assume this cost in exchange for the possibility of improved health outcomes.

Keywords: Self Care, Telemedicine, Monitoring, Physiologic, Telemetry, Hemodialysis, Home.

1 Introduction

Chronic disease is one of the foremost problems facing the sustainability of healthcare systems globally [1]. New cost effective models of care delivery are urgently needed. There are emerging data that support the effectiveness of a systems wide approach of chronic disease management first described by Wagner [2]. The fundamental premise of the model is to dismantle traditional silos by aligning all activities of the health system to support productive interactions between informed, activated (i.e., empowered) patients and a prepared, proactive practice team across the delivery continuum. This model assumes that self-management support strategies will enlighten and empower the consumers, and clinical information systems, and decision support tools will enhance the clinical encounter.

One group that could benefit from this approach is hemodialysis patients. End-stage Renal Disease (ESRD) is a complex chronic condition that is becoming more prevalent, increasing as much as 7% per year [3]. Hemodialysis is a costly resource

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intensive therapy that artificially provides renal function, but can also contribute to a poor quality of life. Home hemodialysis is a simple variant of conventional hemodialysis. It is potentially a more frequent therapy, delivered for longer periods of time, even as the patient sleeps. This requires the patient to dialyze at home with their own dialysis machine; a true hospital-at-home intervention. The improved health outcomes are dramatic. Patients enjoy improved cardiovascular health, improved peripheral circulation, improved sleep quality, and the elimination of dietary restrictions [4, 5]. Patients have been shown to experience greater autonomy by being freed from institutional care. However, there exist patient-related barriers to this form of self-care. Patients worry about the burden on family members, fear the self-cannulation, fear for a catastrophic event, and have low self-efficacy [6].

To address and facilitate patients performing home hemodialysis, a remote patient monitoring intervention was proposed. A user-centric design approach was used in the development of the system [7]. In keeping with this approach, an ethnographic analysis based on Health Belief Model framework [8] was undertaken, determining the barriers to adoption and design criteria for a system that would facilitate mediated patient self-care.

The purpose of this study component was to determine the net effect of this remote patient monitoring on a patient's ability to perform self-care and how it would contrast with the conventional nurse-patient relationship.

2 Methods

A pilot trial of the remote patient monitoring was conducted with eight patients consisting of seven men and one woman, from 22 to 60 years of age. The average age was 46. All patients were new to home hemodialysis treatment. Patients were monitored from between 6-15 months. Semi-structured interviews were conducted with each of the eight study participants. Each participant was interviewed on at least one occasion. The maximum numbers of interviews were three. The numbers of interviews were based on patient availability and when data saturation had occurred. The patient interview script was structured in the following manner; general impressions, pros and cons of the system; impact on well-being, stress, ability to cope, if any; interactions with clinical staff as a result of the use of the system; need for the system going forward; impact on family members. Nursing interviews followed a similar structure where relevant, and had the additional line of questioning relating to: impact on workload; impact on patient care; impact on their role as nurse/technologist. Four staff nurses from Toronto General Hospital, University Health Network Home Hemodialysis unit were interviewed. These are the same nurses who trained the patients and participated in the study by reviewing the dialysis summaries generated by the intervention. Once a sufficient level of saturation was achieved in the interviews, the recordings were transcribed verbatim from audiotape.

Analysis. A general inductive method was using in the analysis of the transcripts. Transcripts were read repeatedly and text segments were coded for potential themes. As the coding framework developed, transcripts were reanalyzed in light of new themes that may have emerged as a result. Coding was not limited to the evaluation objectives and was free to not assume any presuppositions. NVivo qualitative analysis software was used to code the interviews for emerging themes [9].

Description of Intervention. The system consisted of the acquisition, transmission, storage, and processing of patient vital signs (heart rate, blood oxygenation, and blood pressure) and selected hemodialysis treatment parameters of the hemodialysis machine. Rules were developed through discussions with domain experts including nephrologists, nursing staff, and renal technologists. These rules were applied to the data in real-time and alerts generated. These alerts were sent to an on-call technologist staff who received the alerts and assisted the patients as necessary. Additional components included an IP-based pan-tilt-zoom (PTZ) video camera, to allow staff to observe remotely at the

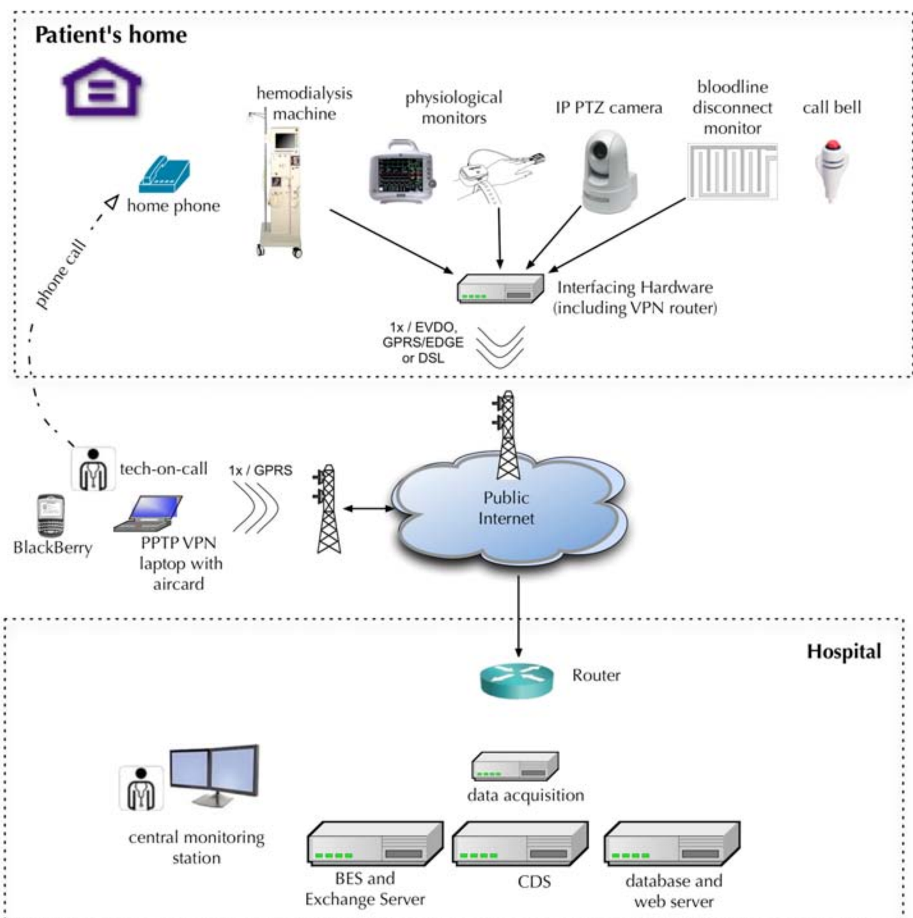

Fig. 1. Diagram of remote patient monitoring intervention for home hemodialysis. Data from the hemodialysis machine, physiological monitor, camera, bloodline monitor, and call bell are securely transmitted to the hospital systems. Data are continually monitored in real-time. Exceptions are routed to staff-on-call to address problems and emergency conditions.

patient's discretion. This was used as an aid in remotely troubleshooting the dialysis machine as well as had the ability to check on a patient during a serious alarm condition. The clinical decision support component of the system generates alerts based on criteria being developed by domain experts. These alerts are sent to the technologist-on-call through a BlackBerry mobile device [10]. The alerts contain relevant information, current patient vital signs, and the patient's home phone number for quick access via the BlackBerry's telephony capability. For further follow-up to the alert, the technologists can VPN into the system, access more physiological and dialysis data, and take control of the IP camera if necessary. (See figure 1)

3 Results

Patient Themes. The main themes from the patient interviews were as follows: *Security and comfort; Dependency; Adherence, Accountability and Privacy.*

Security and comfort. The intervention was found to be particularly supportive of family-caregivers and was viewed as a surrogate for nursing care. Patients remarked on how the system was used to check on details of their treatments, such as the amount of ultrafiltration being performed and their resulting weight and blood pressure. Nursing staff were able to react and advise adjustments to their prescription in a timelier manner. Patients also felt that there was some security and comfort knowing that they were being monitored and that the nursing staff would call when they noticed problems with their treatments. This notion of security and comfort extended to family members as well. The impact of home hemodialysis on family members is often severe and considered a barrier to adoption. The experiences of patients were that family members viewed the monitoring system positively.

Dependency. Though the system was proposed for only transitional use, there was an unwillingness to have it removed. Even those patients with an uneventful transition continued to insist on remaining on remote monitoring. Care providers should be aware that patients perceive remote monitoring as a safety feature and its removal can generate anxiety among patients who have developed an unexpected dependency.

For the most part, patients were uncomfortable or unwilling to part with the system after the study period was complete.

Adherence, Accountability, and Privacy. The monitoring system revealed that patient adherence is a significant issue amongst home hemodialysis patients. Patients failed to routinely perform blood pressure measurements prior to treatment, and on average dialyzed no more frequently than conventional patients, despite the clearly demonstrated health benefits of regular and more frequent therapy. This lack of adherence confirmed staff suspicions, as a result of reviewing poor monthly blood results. However, the use of the remote monitoring system provides direct documentation that the patient is not adhering.

Patients become aware of the level of accountability from the first phone call they receive from nursing staff. For most patients in this study, this access to detailed information of their treatments was not viewed as negatively as with others. Most felt that this was the system at work, ensuring their safety and helping facilitate their care.

These adherence problems raise the issue of accountability of the clinician to the patient as well. The presence of these new clinical data sets out a professional obligation for the clinician to act upon the data and help the patient through periods where they are having difficulty complying with the prescribed level of treatment. Thus, the notion of accountability is indeed shown to be bidirectional between patient and provider.

There was also concern over privacy and the “Big Brother” effect of using remote monitoring. Patients expressed concern over the detailed knowledge their caregivers would have of their schedule, frequency and habits when dialyzing at home. However, the loss of personal privacy through the use of remote monitoring is viewed as necessary for ensuring their safety. They do not distinguish between those aspects of the system that are related to safety and those that could be used to monitor adherence. There was even the view that the accountability was good for them and that it “put them on track” and “keeps you in line”.

Nursing Themes

The nurse’s diminishing role in direct care. The findings from the interviews indicated that the nurses were able to perform a more holistic form of nursing with NHD patients, since they were a dedicated resource to assigned patients. This nursing relationship could continue through the use of remote monitoring, and encompass the following aspects of nursing care: adherence to treatment and patient routine; adjustments to treatment; addressing technique and setup problems.

Monitoring-Mediated Nursing. These aspects of care are either more difficult to do without the use of remote monitoring or are less timely, due to the lack of information at the time the problems occurred. These aspects of care can be considered *monitoring-mediated nursing*, where the nurse continues to care for the patient through access to information that they would have otherwise obtained directly in a conventional setting. Some of the monitoring aspects of care that the nurses would do in conventional hemodialysis have been replaced through automation through the use of the rules engine of the system generating alerts.

4 Discussion

Analysis of the qualitative data indicated a unique relationship between nurse and patient, and their respective roles in providing care. To articulate this relationship, the Orem’s nursing theory may be applied. Healthy individuals normally have developed operative powers and capabilities to care for themselves, known as their *self-care agency*. When ill, an individual’s self-care agency may be diminished, and their care demands may increase significantly. This is especially true of hemodialysis patients, since the therapy to treat their condition is complex. Patients unable to meet the basic requirements to sustain their well-being will require dependent-care to meet their needs.

The imbalance between the therapeutic care demands and the patient’s ability to perform self-care is known as a *self-care deficit*. (See Figure 2). Orem’s self-care deficit theory is used to express the role of nursing in the context of addressing this

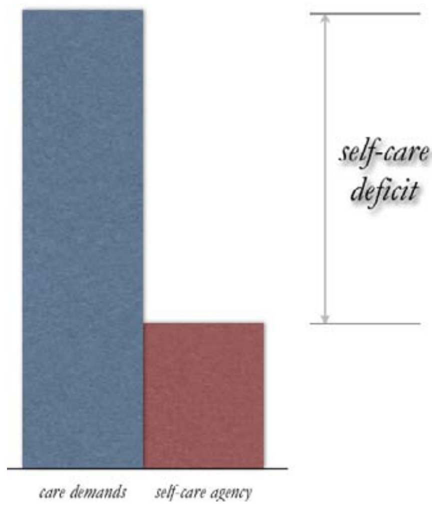

Fig. 2. Patient self-care deficit. Patients with complex chronic conditions typically have heightened care demands and have a reduced capacity to care for themselves, or reduced self-care agency. The unaddressed gap between these demands and agency is the self-care deficit. For conventional hemodialysis patients, this is normally addressed through nursing care.

self-care deficit. Central to the theory is that nurses assist those patients with a self-care deficit by enabling them to regain the requisites for self-care agency [11].

In the case of conventional hemodialysis, the bridging of this gap is never achieved through patient self-care agency alone. The deficit is addressed solely with nursing care. There is no expectation that the patient will ever address this deficit through self-care.

In contrast, the expectation of home hemodialysis patients is that they will address the deficit themselves. The home hemodialysis patients from this study felt ultimately that the responsibility of their care lies with them.

A portion of the deficit is addressed through training, which enhances their self-care agency. Added with the enhancement of patient's self-care agency is the continued nursing support that the patients receive on occasional homecare visits. As shown in this study's findings, nursing staff transition the patient onto the therapy from training by slowly lowering the "patient dependency" on their care. The dependence in never entirely eliminated but is far from the levels that conventional patients receive.

Finally, the results of this study suggest that this self-care deficit is bridged by the addition of *monitoring-mediated support*. This support replaces those nursing functions that were the norm in conventional hemodialysis. This includes the safety aspects of monitoring that have been automated through the rules engine component of the system, and the aspects related to adherence, adjustments to treatment parameters, and addressing technique issues.

This model can be shown to accommodate those patients that have significant dependent care through a family member. This added support may redistribute the care provision between the other components, but does not necessarily replace any

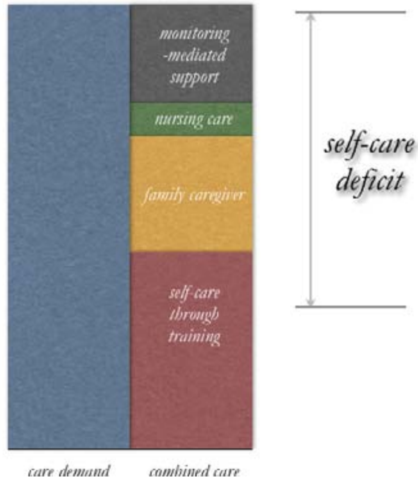

Fig. 3. The patient self-care deficit gap bridged. The component elements include enhanced self-care agency through training, family caregiver support, nursing visits, and monitoring-mediated support.

one component. The needs of family caregivers are often neglected in these cases, and support for them is required to help them cope with the patient care demands. The monitoring support has been shown here to be an effective means to complement this role and that of the nursing staff. (See figure 3)

5 Conclusion

With interventions such as monitoring-mediated support, patients with complex chronic conditions have the capacity of self-care with even the most difficult of hospital-at-home therapies. They now share the responsibility of disease management with their caregiver. With this empowerment comes the realization of a new level of accountability that patients have to their caregiver.

There were patients that expressed concern that their caregivers knew of their deviations from the prescribed frequency and duration of their home therapy, their lack of adherence, and their personal routine. For most, this was an acceptable risk to their personal privacy for ensuring their safety. Nevertheless, policy is needed to ensure that there is appropriate use of information by providers, given the unprecedented access the system allows. Self-care through remote monitoring shows great promise for empowering patients and leading to improved outcomes. This does not come without cost to the patient however, who now has greater personal responsibility and accountability for their health. Promising results from this study indicate that patients, for the most part, are willing to take on this cost in exchange for safety and improved outcomes.

The extension of Orem’s self-care deficit theory demonstrated here attempts to explain the relationships and interaction between self-care, dependent-care, and a technological support intervention. There is significant interest in patient self-care in healthcare currently, due to the positive outcomes and empowerment it can achieve and as a result of the challenges in meeting the care needs of a growing population of patients with chronic disease. Developments in monitoring-mediated support can be shown to assist in facilitating patient self-care with complex therapies.

Innovations such as home hemodialysis cannot reach their full potential if barriers to adoption to continue to exist. An intervention to facilitate the adoption of an innovation is often needed in many other areas of technology adoption. The use of remote monitoring is but one example of this bridging intervention to a therapy or system that will have a net benefit to patients with complex chronic conditions.

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Cognitive Network Infrastructures and Virtualization Platforms in Support of Healthcare Applications

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Abstract. Enormous advances in medical sciences are depicted on their capability to approach previously past-cure diseases, as well as prevent other unpleasant situations. Those advances are often derived from interdisciplinary solutions to complex medical problems, supported by communications and electronics, which target fast, reliable and stable solutions to problems that are demanding in terms of velocity and accuracy. Recent findings in the world of communications, such as the systems beyond the third generation (B3G), as well as the exploitation of knowledge and experience by means of cognitive networks, can be efficiently exploited, in order to support electronic healthcare. Accordingly, the goal of this paper is to present a service-oriented management platform, based on B3G communication systems and cognitive networking principles in order to support novel, electronic healthcare services and applications.

Keywords: B3G infrastructures, cognitive networks, electronic healthcare, management.

1 Introduction

Over the last years, the world of medical sciences has met an unparalleled evolution, mainly reflected on the continuous development and enhancement of various solutions, which has been allowing the a priori diagnosis, prevention, as well as treatment of numerous, previously incurable, diseases. As an outcome of versatile research attempts at a worldwide level, novel answers to numerous medical problems have been identified. Today's advancement of e-health products and applications necessitates the consideration of building seamless information exchange networks. In particular, e-health developments are improving the right of access to quality healthcare, regardless of their personal condition and geographical location, allowing the selection of the appropriate health resource from anywhere at any time. This is especially applicable in emergency situations, where timely retrieval of necessary information might be of extreme importance [1, 2, 3, 4].

The aforementioned advances often call for interdisciplinary research and development strategies, this mainly denoting the utilization of the findings of

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telecommunications and electronics. Specifically, some recent trends in the world of communications, such as the birth of beyond the 3rd generation (B3G) systems [5], depicted on the ubiquitous provision of applications at increasingly high bit rates, have paved the way for several innovative healthcare services and applications. Additionally, the advent of cognitive networks, which exploit past interactions with the environment, in taking future decisions regarding their behavior, is expected to facilitate several medical approaches, such as patient management technologies in telemedicine and remote diagnostics, which constitute key research aspects nowadays. All above have rendered the cooperation of medicine with telecommunications, a fundamental (almost prerequisite) factor for any further steps forward.

In the light of the above, the goal of this paper is to discuss on how B3G wireless communication systems, enhanced with the advantages of cognitive network infrastructures, can serve as enablers for the effective management and direction of novel healthcare applications. For this purpose, it first presents an indicative scenario envisaged to involve medicine and electronics, which necessitates the specification of innovative, interdisciplinary solutions. Then, it provides an overview of B3G wireless communication systems and cognitive networking principles, emphasizing on aspects of interest to electronic healthcare. Aligned with the above, the paper then proposes a service-oriented management platform for offering virtualization and cognition, with the scope to facilitate existing healthcare applications. The paper concludes with some summarizing remarks and aspects of future activities.

2 Indicative Healthcare Scenario

The goal of this section is to present an indicative scenario that reveals the need to support healthcare applications with advanced B3G, cognitive networking features. This refers to the retrieval of information that is demanding in terms of quality of service (QoS), so as to ensure the effectiveness of the related application in emergency situations.

The scenario involves an ambulance carrying a patient, and moving at a very high velocity towards a District General Hospital (DGH). Throughout the ride, the ambulance's co-driver is able to collect information regarding the patient's condition, using the appropriate electronic instruments, which can analyze this information. The instruments reveal the existence of a certain danger for the patient's life; consequently, there is need for quickly specifying a treatment procedure (before reaching the DGH), according to (i) the patient's history and (ii) radiological results. The healthcare application considered is able to interchange information with the DGH (inform the DGH upon the incident, so as to enable it to be prepared for efficiently handling it) and depending on the specific need, perform any radiological procedure on the patient, by means of the co-driver. Depending on the patient's personal data, a search is performed within a database in order to (i) identify the patient's history and (ii) check whether a similar incident has been confronted in the past. The doctor inside the communicating DGH is able to watch the patient via video in order to obtain a personal impression upon the incident and thus take any necessary decisions regarding the patient. Potentially there will be need to perform a certain radiological process upon the patient. Subsequently, the doctor is able to specify the appropriate treatment procedure.

A business case corresponding to the aforementioned scenario is presented in Fig. 1.

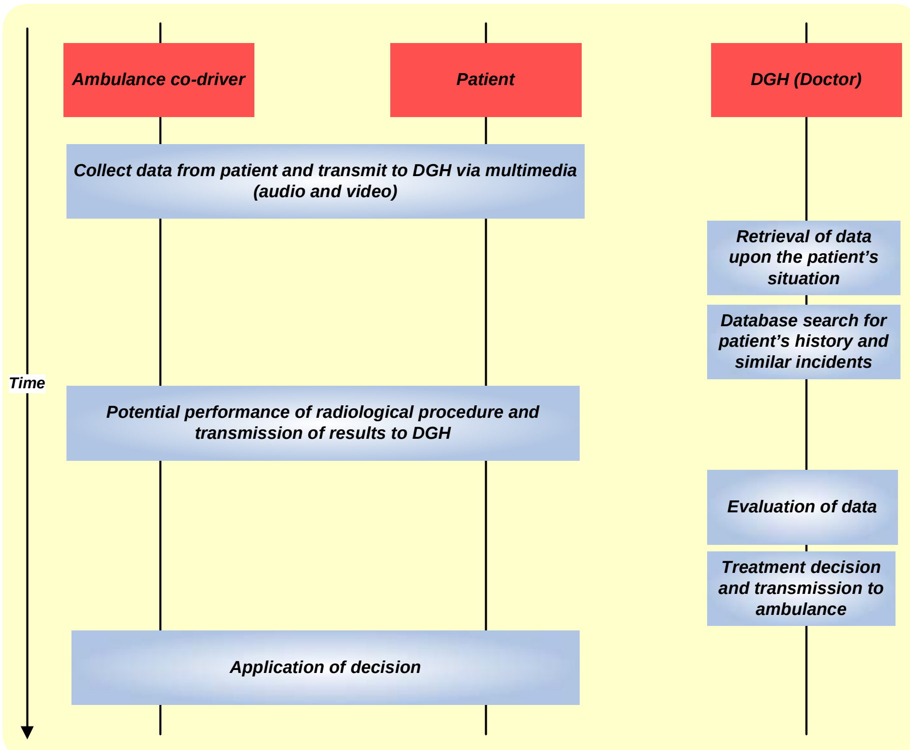

Fig. 1. Healthcare Scenario

The scenario presented above leads to twofold deductions.

First, the necessary time for taking the decision upon the treatment procedure can be significantly reduced, through the continuous communication between the moving ambulance and the associated DGH's doctor. The doctor is informed upon the patient's situation, history and also radiological results (which would be more time-consuming, if completely executed inside the DGH) and may reach to the desired decisions faster and thus more effectively. This benefit is of great significance, since it might be critical for the patient's life.

Second, the scenario assumes that the ambulance is capable of being ubiquitously connected to the DGH in a wireless manner, constantly exchanging information at very high bit rates, which might be difficult while the ambulance changes locations fast. This calls for an enhanced support by means of a telecommunication infrastructure which will allow the transmission of data at high QoS levels, seamlessly.

The next section accordingly, provides an in-depth view of the current wireless communications landscape, so as to serve as a facilitator for the scenario. Accordingly, section 4 describes the proposed infrastructure for such demanding electronic healthcare applications.

3 Wireless, B3G Systems

Over the last decade the world of telecommunications has been undergoing crucial changes, which have brought it at the forefront of international research and development interest. Creative competition among industrial manufacturers, network operators, service providers and academia, through work in research projects, fora and standardization bodies, has resulted in the advent of a multitude of innovative technologies and associated products. Special interest has been drawn in wireless communications, since they are flexible in facilitating novel features, while they also encompass the increasingly desirable concept of mobility. In this respect, today's wireless world features numerous versatile Radio Access Technology (RAT) standards, such as 2G/2.5G/3G mobile communications [5], the IEEE 802.11 and IEEE 802.16 suites of wireless local area networks (WLAN) and wireless metropolitan area networks (WMAN) respectively [6], broadcasting technologies [7], and also Software Defined Radio enabled (SDR) segments [8].

However, wireless systems, in contrast with traditional wired ones, suffer from several dependability problems, including reliability and availability issues [9]. In fact, no specific RAT can be considered trustworthy to confront by its own all contextual situations. Therefore, the exploitation of their coexistence, through their potential cooperation and complementary use, stands as a prerequisite for increasing the dependability of wireless infrastructures. This results in, so called, Beyond the 3rd Generation (B3G) vision [10]. In addition, constant context changes render the different RATs less predictable in terms of Quality of Service (QoS) provision. Consequently, the adaptation of B3G infrastructures to environment requisitions is a key factor that facilitates the realization of the B3G vision.

Cognitive systems [11] are seen as a major facilitator of the B3G vision. Cognitive systems, in general are capable retaining information from past interactions with the environment, transforming this information into knowledge and experience and planning their future behavior accordingly. In the case of wireless networks, this can be translated as the capability of continuously adapting to changing environmental conditions and/or user needs [12]. Adaptation is mainly realized by means of self-management and typically involves machine learning [11].

Considering the above situation, The 3rd Generation Partnership Project (3GPP) [5] has been working on the evolution of the 3G mobile system, defining the architecture shown on Fig. 2, focusing on GPRS Evolved Radio Access Network (GERAN), UMTS Terrestrial Radio Access Network (UTRAN) and Evolved Radio Access Network (RAN) base stations and controllers, also SDR segments, all connected to the, so called, Evolved Packet Core (EPC) network. Certain interfaces allow the interconnection of those versatile control and management entities.

Following the 3GPP architecture described above, several applications, novel and existing ones can be supported. In fact, versatile management and control entities may direct the operation of an infrastructure that complies with this architecture. Following this paradigm, the next section proposes a service-oriented management platform for offering virtualization and cognition, and also for supporting electronic healthcare applications, in conjunction with the scenario presented in section 2.

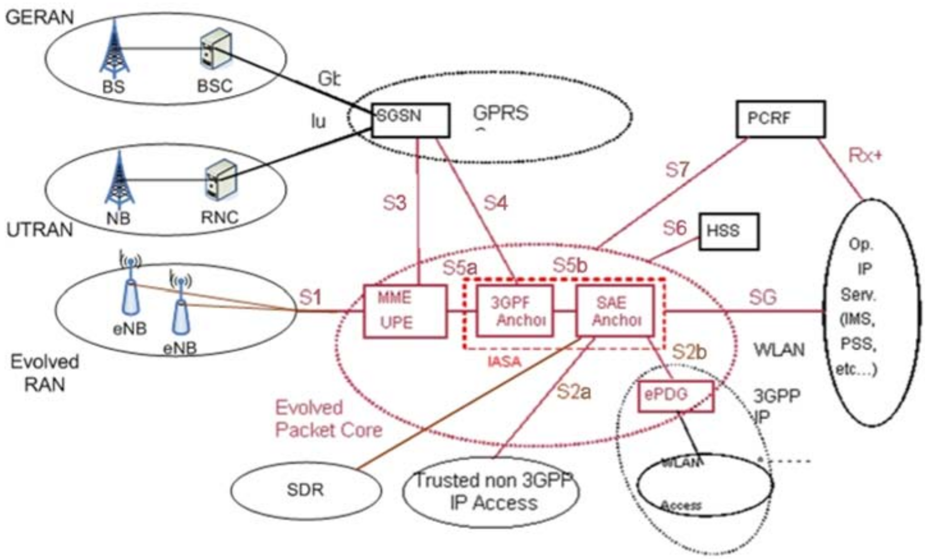

Fig. 2. The 3GPP view on the wireless B3G world

4 Service-Oriented Management Platform for Offering Virtualization and Cognition

As a general deduction from the discussion above, a generic architectural framework to support electronic healthcare applications must dispose certain characteristics of a service-oriented platform. First, it should allow the alternative utilization of various RAT standards during the communication among the ambulance and the DGH. Second, to do so, it should be adaptive (reconfigurable), so as to allow for fast responses to the varying external conditions in the wireless landscape, due to the ambulance's motion. Third, it should be cognitive, so as to retain information from previous incidents and potentially accelerate its response time, in the case that a similar incident has been anticipated in the past. Furthermore, the patient's history might drive future decisions in a cognitive manner and thus lead to the desirable results.

A platform that is envisaged to host diverse electronic healthcare applications, by offering virtualization and cognition (Healthcare Services Oriented – Cognition Management Platform - HSO-CMP), is depicted on Fig. 3.

In general, the proposed platform is expected to be composed of a number of functional elements.

First, hospital (DGH) services which exist also today might need some improvements / enhancements, so as to enable fast transmissions of data at real time, in conjunction with the latest trends in the wireless world. Second, a picture archiving and communication system is needed, for keeping record of incidents, as well as for being responsible for providing the correct information regarding the specific condition of a patient. Third, a radiology information system is needed in the case that certain radiological operations need to be immediately performed upon the patient,

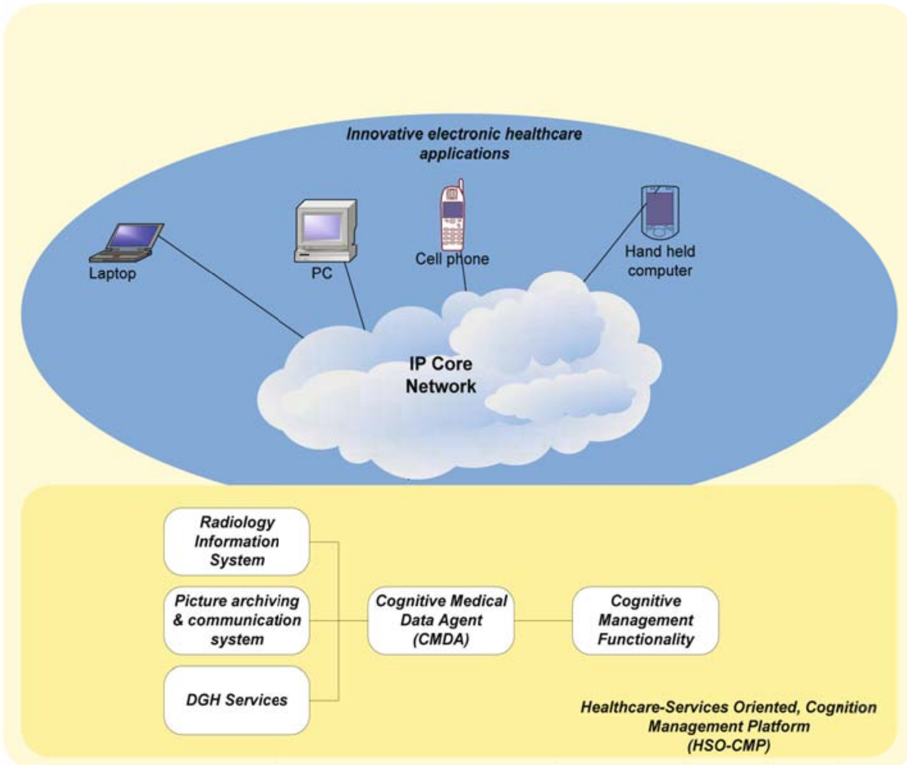

Fig. 3. Healthcare Services Oriented – Cognitive Management Platform (HSO – CMP)

before the doctor is able to reach a decision. Fourth, a cognitive medical data agent (CMDA) might act s a broker, unifying the platform's components. In particular, all data transferred through the platform are recorded by the MCDA, enabling it to locate them fast, if and when needed.

The aforementioned components are managed by an overarching management functionality component. This component should support cognition, in terms of disposing the necessary machine learning equipment that could judge whether an incident anticipated in the past might serve as a guide in deciding upon the appropriate treatment scheme, by proposing potential solutions to the DGH doctor. In fact, this component should be in continuous contact with the DGH doctor, so as to enable the doctor exploit its cognitive features.

In general, the HSO-CMP is under continuous evolution and can be significantly elaborated, so as to be put into effect in realistic emergency situations. After the specification of its fundamental features, the detailed operation of its components, as well as the interfaces that enable their interactions, should be thoroughly analyzed. An indicative message sequence chart (MSC) that can represent the platform's operation is depicted in the following figure.

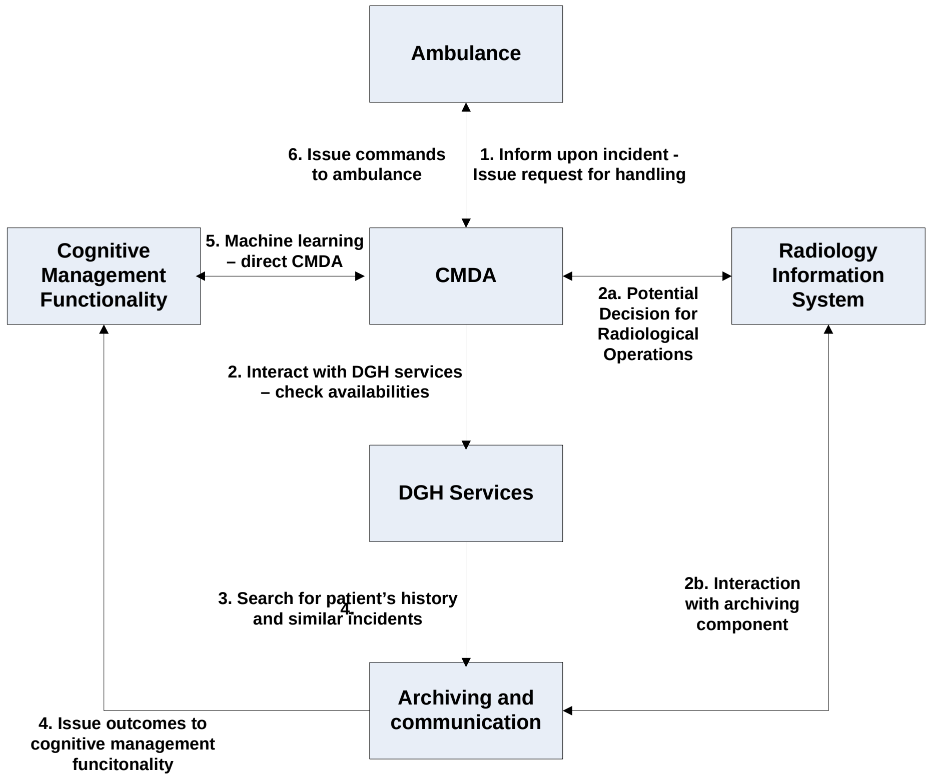

Fig. 4. Indicative Message Sequence Chart

First, the ambulance issues a request regarding the specific incident, towards the CMDA. The CMDA then interacts with the DGH services component, in order to check their availability. The identification of the available services is performed with the help of the archiving and communication component. In addition, there might be need for radiological procedures, so a message exchange been the CMDA, the radiology information system and the archiving and communication components, takes also place. Then, the outcomes of the aforementioned interactions are transferred to the cognitive management functionality component, which issues directives towards the CMDA, exploiting past knowledge and experience. Finally, the doctor is in position to decide upon the suitable treatment scheme and the ambulance is notified accordingly.

5 Summary and Conclusions

Electronic healthcare applications constitute a finding of medical sciences which can significantly facilitate their evolution, by contributing to the prevention as well as treatment of several unpleasant situations / diseases. In this respect, the goal of this paper was to propose a service-oriented management platform for offering virtualization and cognition in support of electronic healthcare applications. The paper has presented an indicative scenario envisaged to be associated with healthcare, which calls for support on behalf of telecommunications, and it has presented such an architectural framework as a manner to direct such an (emergency) scenario, with the general goal to efficiently, transparently and securely manage electronic healthcare applications. It is expected that several electronic healthcare applications can operate on top of such a generic infrastructure, emphasizing on applications that are demanding in terms of QoS levels, usually associated with emergency situations. The further elaboration of the architectural framework presented, as well as the identification and development of even more innovative electronic healthcare applications that could be supported, will form part of our future activities.

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Device Data Protection in Mobile Healthcare Applications

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Abstract. The rapid growth in mobile technology makes the delivery of healthcare data and services on mobile phones a reality. However, the healthcare data is very sensitive and has to be protected against unauthorized access. While most of the development work on security of mobile healthcare today focuses on the data encryption and secure authentication in remote servers, protection of data on the mobile device itself has gained very little attention. This paper analyses the requirements and the architecture for a secure mobile capsule, specially designed to protect the data that is already on the device. The capsule is a downloadable software agent with additional functionalities to enable secure external communication with healthcare service providers, network operators and other relevant communication parties.

1 Introduction

The Internet and mobile networks have penetrated the healthcare sector due to their increased functionality, low cost, high reliability and easy-to-use nature. During the recent past, research activities have been focused on achieving portability of medical records, monitoring real-time health status of the patients, and enhancing the concept of online diagnosis and telemedicine. In a broader sense, such healthcare applications can be termed as "m-health". M-health is about an emerging set of applications and services that people can access from their web-enabled mobile devices. Even though the technology makes m-health possible many open issues still exist in the mobile healthcare environment such as security of electronic data transactions, mobile user authentication and secure data storage in a mobile device with protecting privacy. This paper presents a logical architecture for an on-the-phone security agent (a "Security Capsule"). This security agent can, in a single-sign-on mobile healthcare environment, rapidly improve the security by enabling authentication to healthcare service providers and also by protecting the privacy on the data storage on the phone.

The security capsule is owned by a trusted entity and it is securely downloaded and installed into the mobile device. The trusted entity can be a government body, National Health Service in UK or a mobile operator and this paper names

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the trusted entity as the authentication service. It is assumed that the mobile capsule itself is secured but the mobile device is considered to be an un-secured object and the communication between the mobile device and external parties is vulnerable to security attacks. Therefore, the security capsule is invented as a solution to protect sensitive medical data from security vulnerabilities during the transmission and to prevent losing or stealing the medical data stored in mobile devices. In the current mobile device technology, the encrypted sensitive information can be transmitted to a mobile device but decrypted plain information is stored in common storage area of the mobile device. So the sensitive information in a mobile device is vulnerable to un-authorized accesses. The application level password protection can be applied to sensitive information but the data can be retrieved in readable format from the hardware level. Therefore, if the mobile device is lost or stolen then an authorized party can acquire sensitive information from the mobile device. The proposed security capsule stores medical and sensitive data in encrypted format and those are decrypted only when the user wants to view the information. Meanwhile decrypted data is not stored inside the mobile capsule and is viewable to the user over a read-only interface of the mobile capsule. Therefore this data cannot be saved inside the mobile device or transmitted to another mobile user.

A number of publications [5,6,8] describe the use of the healthcare applications from a mobile device. According to the knowledge of authors none of those publications discuss an approach to secure the sensitive data that are stored within a mobile device. Meanwhile there are publications on security mobile agents but those publications fail to address the protection of the data security and privacy using token management systems and release of a read-only interface to the mobile users. In addition to the proposed, the mobile capsule can establish secure communications channels with external service providers and other security capsules. The Java Micro Edition, Symbian C++ and Python are some of the programming languages used to implement agents in mobile devices. Publications [4,11,12] discuss implementations of security mobile agent in Java and Telescript with addressing some of the existing security issues. In [2] Borselius discussed some security features and properties of agents and multi-agent systems. Picco in [9] presented evidence of benefits a mobile agent can potentially achieve and he illustrated architectural foundation for a mobile agent.

In addition to the data protection, the security capsule needs to provide at least two more functions: (1) to enable secure authentication to remote communication parties and (2) to enable secure encrypted communication channels from the mobile device to the remote communication parties. The security capsule authenticates and authorizes itself with the authentication service and the service providers before establishing any data transmission communications. The trust needs to be negotiated and established between the requestor party and the relying party through the capsule before sharing any sensitive information. The trust and authentication information is exchanged using security tokens. The security capsule will acquire security tokens from authentication service and healthcare service providers after each successful authentication, authorization or trust negotiation process. Following this, the data encryption is achieved through the message level security protection using XML security features for data transmission. The required secure protocols for this are defined in some of our previous publications [13,14].

This paper presents the case for the security capsule and identifies the main requirements for the provision of the three main functions of the capsule: data protection on the device, secure authentication and data encryption. These three functions provide the necessary privacy and security for m-health application users. The rest of the paper is organized as follows. Section 2 presents the standard m-health communication architecture, identifies the main actors and their relationships. Sections 3 and 4 describe the logical architecture of the security capsule and the requirements for its most important units.

2 Mobile Healthcare Architecture

We observe an m-health architecture with three types of main actors; a mobile device with a secure capsule, authentication service and service provider as shown in figure 1. The patient or service provider staff with the mobile device accesses the services via a bandwidth-constrained mobile station, comprising the mobile device and the service-enabling SIM card connected to a mobile operator over the UMTS network. The authentication service is connected to the registered service providers such as healthcare service provider, private medical centre or insurance service providers to provide healthcare services to patients.

The mobile device authenticates with the authentication service by using credentials that are stored within the mobile capsule and SIM credentials at the mobile operator. Once successfully authenticated with the authentication service, the staff/patient with a mobile device can request access to the services at service providers. The authentication and authorization links between the mobile user and service providers are established based on Single-Sign-On [7] technology

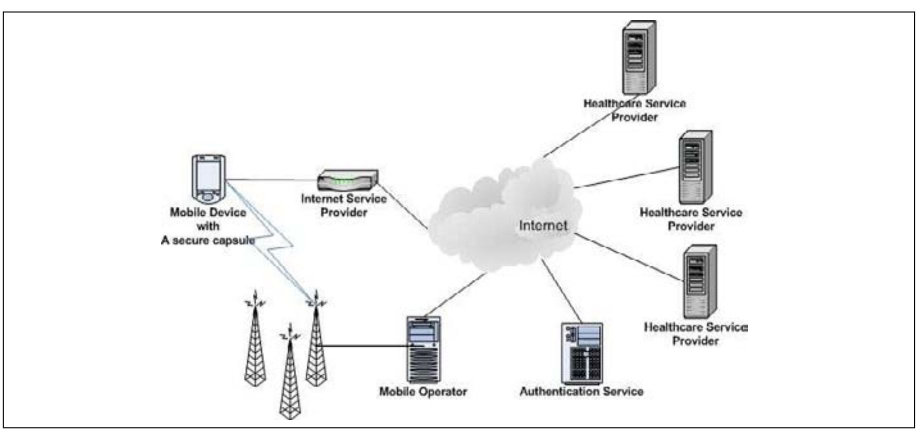

Fig. 1. Mobile Healthcare Architecture

at the authentication service. Services and information sharing between a service provider staff and a relying service provider in distinguish security realms takes place after a trust negation between two service providers. The implementation of all the service providers and the authentication service are based on the Service Oriented Architecture [1,3]. Service providers communicate with the patient and the mobile operator using the Hypertext Transfer Protocol [10]. The message flow uses the latest XML encryption, XML signature and XML Key Management technologies that are much faster and consume less power for secure mobile applications.

3 Security Capsule Architecture

The logical architecture of the security capsule consists of storage and security units to preserve the data and message security. Figure 2 presents the main components, interfaces and the information flow in the security capsule.

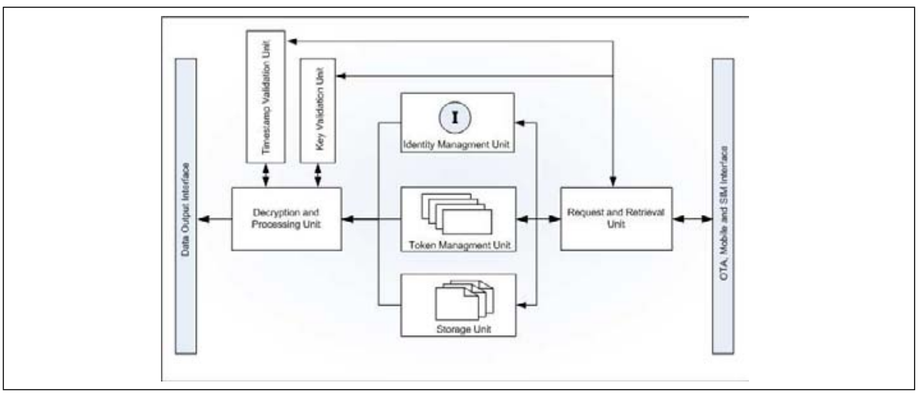

Fig. 2. Security Capsule Architecture

Request and Retrieval unit establishes communication links with authentication providers, service providers, SIM/USIM and the mobile device over an interface. This interface is named as OTA, Mobile and SIM (OMS) interface and it supports connections to third party web services and OMS interfaces of other mobile capsules. Income data flow consists of identity objects, tokens and encrypted data and the data flow is respectively distributed to Identity Management Unit, Token Management Unit and Storage Unit. The Decryption and Processing Unit decrypts encrypted data and the input flows are shown in figure 1. This unit outputs the decrypted information over the data output interface to the mobile user. The security capsule provides read-only and un-savable interface to the mobile device and this data cant be saved in the mobile device or transmitted to another mobile device.

3.1 Request and Retrieval Unit

This is the communication unit of the security capsule and this unit establishes secure communication links with service providers and authentication services over XML messages or web service invokes. Meanwhile communication between two secure mobile capsules is established by the request and retrieval unit. This unit validates incoming data flow and protects out going data flow using XML security features [13].

3.2 Identity Management Unit

The security capsule acquires an identification object from the authentication service during the download and registration phase. This identification object is used as a security credential for authentication and authorization with authentication service. Meanwhile service providers from different realms should authenticate and authorize the mobile capsule before disclosing any services. The service provider issues an identification object to the mobile capsule after a successful authentication and authorization to services. These identification objects are named as service provider identification objects and those are saved and managed by the Identity Management Unit. Meanwhile public key infrastructure (PKI) information of the mobile capsule is saved with the Identity Management Unit.

3.3 Token Management Unit

Various types of tokens are utilized during the communications between the mobile capsule and the service providers such as registration, authorization, authentication and trust tokens. Format and the structure of these tokens are discussed in the token management section. These tokens grant authority to the mobile capsule to acquire services and data from service providers. The decryption and processing unit doesn't process encrypted data unless the valid token is present for the encrypted content. Tokens and encrypted data are sent to the mobile device at two different instances and the capsule save those tokens in the Token Management Unit. Tokens are indexed in the Token Management Unit with reference to the service provider identity and timestamp. It provides tokens to the Decryption and Processing Unit for data decryption process. Meanwhile tokens are expired after the specified token lifetime. The expired tokens are automatically achieved or deleted to save the storage space and the processing power of the mobile device.

3.4 Storage Unit

Encrypted data from service provider are saved in the storage unit of the mobile capsule. These encrypted data are indexed with service provider id and those are automatically deleted or archived after the decryption to save the storage space of the mobile device.

3.5 Decryption and Processing Unit

This is one of the main units in the security capsule. This unit represents a decryption algorithm to decrypt encrypted data from service providers. Each encrypted data is linked with one or more security tokens to prove the mobile capsule's authorization to decrypt the encrypted data. Therefore Decryption and Processing Unit is linked with the Token management unit to fetch the necessary tokens for the decryption process. The token generated timestamp and the token lifetime are concatenated to each token. This algorithm verifies the freshness of the tokens and encrypted data before decryption. Present timestamp is acquired using the Time Stamp Validation unit. Tokens and encrypted data are signed by the secrete keys to protected the integrity. The public key certificates and other key information are retrieved over the Key Validation Unit. The decrypted data is transferred through the data output interface to the mobile device. The output of the interface is in read-only format and decrypted data is not saved with in security capsule at any instance. The decrypted information can't be saved within the mobile device or can't be transmitted to outside the mobile device since the Data Output interface provides and read-only and un-savable interface.

4 Token Management

Different types of tokens are utilized in this proposed mobile security capsule and these tokens provide authorization to successful data decryption. Tokens are issued by authentication service and service providers to register and authenticate the mobile user to use sensitive data and services. The token management unit is one of the main functional units in the mobile security capsule since it stores and manages these tokens. These tokens basically consist of issuer's identification, token identification, session key information, timestamp and token lifetime. The token will be deleted or archived after the token life time is expired. However token management unit can request for a new token from the service provider for expired tokens. All the tokens are constructed in XML format and tokens are integrity protected by signing the contents using the issuer's private key. Meanwhile token is encrypted to protect the confidentiality using a session key or the public key of the mobile capsule. Following sub sections describe some of the tokens in the token management unit with their XML structures. The below abbreviations are used for token representation.

- SMC = Secure Mobile Capsule;
- SP= Service Provider
- AS = Authentication Service
- TS = Time stamp
- tsK = Session Key
- s_{N_K}(X) = The signature of data X using secret key K of entity N
- e_{N_K}(X) = The encryption of data X using public key K of entity N

4.1 Registration Token

(RT=$e_{MSC_{public}}(s_{AS_{private}}$[UID||Lifetime||TS])) The registration token is used by the authentication service to identify and authenticate legitimate mobile devices before establishing communications with service providers. The registration token is issued by the authentication service during the download and installation phase of the security capsule. The security capsule should have a valid registration token for communication. The mobile security capsule sends the registration token to authentication service and the authentication service verifies it before disclosing access service providers. This token belongs to the authentication service and this verified by the authentication service. Therefore the token is signed by the private key of the authentication service and encrypted using the public key/session key of the security capsule.

4.2 Authorization Token

(AT=$e_{MSC_{public}}(s_{AS_{private}}$[UID||SID||tsK||KeyLifetime||Lifetime||TS])) The authorization token is used to authorize the mobile device to access services from the service provider. This token is issued by the service provider and it consists of user identity, session identity, time stamp and session key and key life time. The authorization token is signed by the service provider private key to protect the data integrity and the token is encrypted using the public key of the mobile security capsule. Authorization tokens are linked with the encrypted data from service providers and a valid token has to be present for a successful data decryption.

4.3 Trust Token

(TT=$e_{MSC_{public}}(s_{SP_{private}}$[TTID||SPID||ALT||Lifetime||tsK||TS]))The trust token can be considered as the trust agreement between the mobile device and the service provider. The trust tokens are generated using some trust evaluation algorithms in the trust federated environment by service providers or authentication service. The trust token represents the trust acquired by the mobile user to view some sensitive data from a service provider. The service provider generates the trust level which is named as assigned trust level (ATL) and it is concatenated to the trust token. This token should be presented to Decryption and Processing unit for data decryption functionality. The trust token is singed by service provider private key and the confidentiality is protected by encrypting the token by the public key of the mobile security capsule. The trust token will expire after the token lifetime and the Trust Management Unit can request a new trust token from the service provider.

5 Conclusion

The mobile communication technologies have been introduced to health industry as a cost effective, faster, reliable and user-friendly solution. Since health sensitive information is transmitted in the network it is vital to protect patient's privacy against misdemeanours activities. This paper proposes a security capsule with token management architecture to enable the secure transmission and storage in a mobile device.

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Persuasive Mobile Health Applications

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Abstract. With many industrialized societies bearing the cost of an increasingly sedentary lifestyle on the health of their populations there is a need to find new ways of encouraging physical activity to promote better health and well being. With the increasing power of mobile phones and the recent emergence of personal heart rate monitors, aimed at dedicated amateur runners, there is now a possibility to develop "Persuasive Mobile Health Applications" to promote well being through the use of real-time physiological data and persuade users to adopt a healthier lifestyle. In this paper we present a novel general health monitoring software for mobile phones called Heart Angel. This software is aimed at helping users monitor, record, as well as improve their fitness level through built-in cardio-respiratory tests, a location tracking application for analyzing heart rate exertion over time and location, and a fun mobile-exergame called Health Defender.

Keywords: eHealth[1], Persuasive, Exercise, Mobile.

1 Introduction

It is well accepted that the increasing sedentary lifestyle of many industrialized societies is helping fuel the dramatic rises in type 2 diabetes, chronic heart disease and obesity. In the UK it has been reported across the various News media that recent estimates suggest that over 60% of males and 50% of females will be clinically obese by 2050, and that 40% of school age children are overweight or obese. In addition to this, depression and mental ill health is set to be one of the fastest growing conditions in UK with 1 in 6 of the population suffering from a neurotic disorder [7]. Whilst the overall reasons for this are may seem complex there is one simple thing we can all do to improve this situation, exercise.

Exercise not only makes the body stronger, fitter and more flexible. It also helps to reduce the risk of illnesses such as heart disease and stroke, the latter being the greatest single cause for severe disability in the UK [9]. It is widely recommended by experts that everybody should undergo at least 30 minutes of mild exercise 5 times a week, but with our ever increasing busy life styles we try to find new ways in which to persuasively encourage people to undertake such physical exercise.

In the early years of this decade health clubs where at the peak of their popularity with around 8.7 million members in Britain, though numbers have been falling

[1] eHealth 2008, September 8th and 9th, 2008, City University, London EC1.

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rapidly in recent years. Surveys show that 6 months after joining there is a dropout rate of around 60%, and that near 20% of members only attend once a month [10]. With attendance to health clubs dropping, new technologies are arising to try to promote individual personal exercising.

Nike and Apple joined forces to release Nike+ iPod Sports Kit which calculates distance and pace for a walk or run while storing and relaying back the data to the user as they listen to music. The data can later be uploaded to Nike's website for analysis, as well as sharing and comparing it to other members of the community. Similarly Adidas and Samsung released miCoach, which consists of a specific Samsung mobile phone connected to a heart rate monitor and external stride sensor with very similar functionalities to the Nike+. Both approaches are great at monitoring physical exercise though limiting as they are principally targeting users already involved in physical activities, required to purchase specific gadgets that can only be used together. With the increasing power of mobile phones and the ability to connect them between emerging health monitoring devices, as well as their adaptability to the mobile health sector [5], is making it possible to develop and deploy mobile heath promoting applications at low prices to an ever growing mobile community.

Persuasive technologies [2] can be described as those that attempt to change user attitudes and behavior in some way or another. In this paper we present a novel persuasive mobile health application called Heart Angel intended to encourage users to assess, monitor and improve their fitness level.

2 Heart Angel

Heart Angel is a structured exercise and health monitoring application written in J2ME developed to help people measure, monitor, record, and improve their personal health whether starting or already indulged in physical activities. This is achieved through in-built cardio-respiratory tests, a HR and position tracking application, or a mini-game inspired by the old arcade classic Space Invaders called Health Defender. The application makes use of a Bluetooth enabled mobile phone connected to a Heart Rate Monitor (HRM), as well as an inbuilt Global Positioning System (GPS) receiver to collect data on users HR, as well as location trail.

Heart Angel incorporates a series of tests developed to measure and improve health. Users can choose between a 3 minute Step-Test, or the recognized Rockport Test, to measure and monitor their current fitness level. Results can be saved to a text file for future analysis and interpretation through the application itself, or downloaded to a personal computer.

Users requiring a detailed analysis of performance can use the phones inbuilt GPS receiver together with the HRM. This allows data on HR at a given time for a given location to be recorded at 2 second intervals and then saved as a text file on the device for download. Exertion Maps can then be drawn for analysis seeing when, where, and why, exertion was highest during workouts. Multiple workouts for the same circuit can then be analyzed over time to observe improvements in performance.

In the following paragraphs we present the different cardio-respiratory workouts incorporated in the application, as well as how Heart Angel tries to persuasively encourage users to exercise on a regular basis through real-time physiological data and results feedback. Further development to the application will also be discussed.

2.1 Connectivity

To make use of the Heart Angel application users are required to enable Bluetooth connectivity on their mobile phones, as well as strapping up to the Alive Technologies HRM Chest Strap, as shown in Fig. 1. Initial testing showed that the HRM was prone to errors due to the nature of the connection between the Chest Straps and a user's skin, as well as friction generated between these when users where in motion. Dampening the area of contact minimized the frequency and range of the errors, but a five value filtered average for HR was implemented for HR feedback.

Fig. 1. Alive Technologies HRM Chest-Strap connected to phone via Bluetooth

2.2 Cardio-Respiratory Workouts

Heart Angel provides a selection of workouts from which users can calculate, monitor, and improve their physical fitness. Following is a description on each focusing on their functionality.

2.2.1 Tecumseh Step-Test

This is the simplest cardio-respiratory workout available for calculating user fitness level. Users are required to enter details on gender and age, and have the option to save their results for future interpretation through the application it self, or download to a personal computer.

When ready, users perform a 3min step-test performing a four-step cycle (R-foot UP, L-foot UP, R-foot DOWN, L-foot DOWN) ideally completing an average of 24 cycles in one minute on an 8inch (20cm) bench/step. An inbuilt pace keeper can be enabled by users to help them keep to this pace. Once completed user HR is captured, and their subsequent results calculated and displayed on the phones screen. During the cardio-respiratory test the last 115 HR values for a user are displayed via a line graph at the top of the screen, allowing users to visualize HR exertion over time.

2.2.2 Rockport Test

Users can also perform the internationally recognised cardio-respiratory test, The Rockport Test in which they are required to walk a distance of one mile as fast as possible. As in the Tecumseh Step-Test, users are required to enter data on gender, age as well as weight, and choose whether to save their results for future comparisons.

When completed the walk, users stop the workout and a measure of their current fitness level as well as their VO_2MAX[2] is displayed, see Fig. 2 leftmost screenshot. Again the last 115 HR values for a user are displayed via a line graph at the top of the screen, allowing users to visualize HR exertion over time.

To try to ensure that results are as accurate as possible, the application makes use of a running filter which collects user HR every 15 seconds as well as at workout completion. Such filter tries to minimise errors due to users increasing their pace near completion, giving a higher than normal final HR.

2.2.3 Free-Jog

For users more concerned in analysing and comparing past and future workouts whether it be walking, jogging or cycling, Heart Angel includes it's "Free-Jog" application which allows use of a GPS receiver. Users are required to enter details on age and resting HR, entered manually or automatically collected via the HRM, as well as being able to enter a description on their location which will be saved along with the results.

By knowing a user's resting HR and age it is possible to calculate their maximum HR and consequently their different HR Training Zones. This information is then relayed back in real-time to the user through a pie chart displayed on the mobile phone's screen showing at what Training Zone intensity they are currently working at as well as the linked health benefit it carries. The last 115 HR values for a user are again displayed via a line graph at the top of the screen, allowing users to visualize HR exertion over time, see Fig. 2 rightmost screenshot.

Through the use of the inbuilt GPS receiver, data on user position can be collected together with current HR and time. This data is saved at 2 second intervals to a text

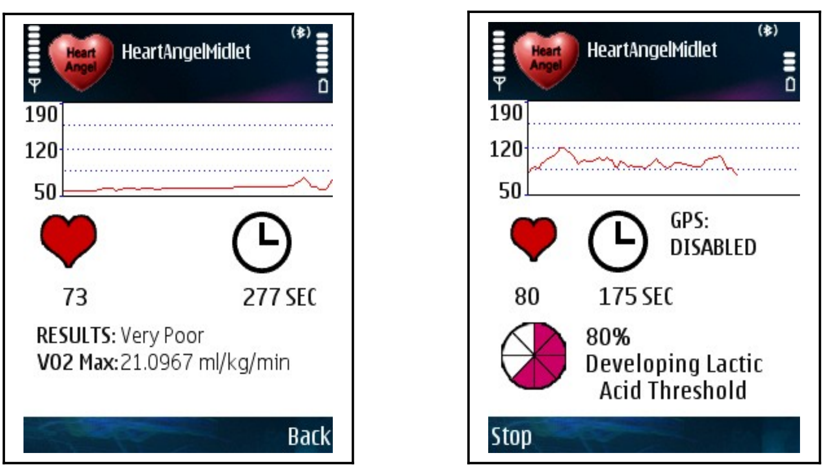

Fig. 2. Rockport-Test (left) & Free-Jog (right) display and result layouts

[2] The volume of oxygen that can be consumed while exercising at maximum capacity, or the maximum amount of oxygen in millilitres that can be consumed in one minute per kilogram of body weight.

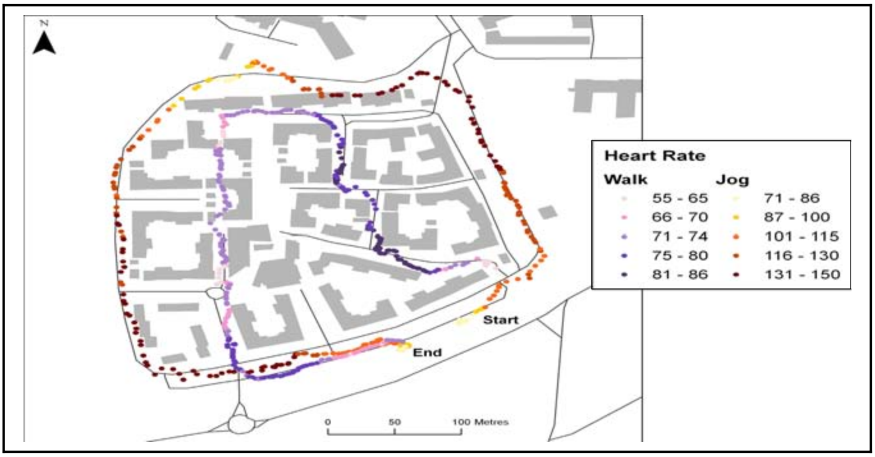

Fig. 3. Exertion Map showing two routes for Lancaster University's SW Campus[3]

file on the mobile phone's memory for download. From such file it is then possible to draw Exertion Maps for individual or multiple workouts and have a much improved visual representation of HR exertion over time and location. Though Heart Angel does not provide the means to plot such graphs, Fig. 3 represents an exertion map showing two different routes for Lancaster University's South-West Campus in which HR exertion can be analysed with knowledge of the terrain.

2.2.4 Health Defender Exergame

Health Defender is an Exergame inspired in the old classic Space Invaders which makes use of a HRM to collect and relay real-time HR data back to a player. Such data is used to inform users on their current HR exertion during game play, and trigger Bonus events. It is through these bonuses that Health Defender tries to encourage users to physically exercise by raising their HR to obtain such bonus. The objective of the application is to encourage players to exercise during game play to both improve gaming experience, as well as personal health [3].

2.3 Persuasive Physical Exercise through User Feedback

Heart Angel tries to persuade users to keep using the application, and therefore continue exercising, by providing real-time feedback on user current HR exertion and relative HR Training Zone. Users have a real-time visual representation of the intensity at which they are exercising at together with a report on the health benefit that exercising at such intensity is providing them. By reporting such information to users while actively involved in the physical workout, these are encouraged to either maintain or further increase their physical exertion as they are reassured that a physical benefit is being achieved.

Allowing users to keep track of past workout results is also important to allow for observations in any physical fitness improvement. Before initializing any of the

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[3] Subject to Crown Copyright OS Landline 2006. An Ordnance Survey/Edina supplied service.

inbuilt cardio-respiratory test users may choose to save their results for future interpretation and analysis through the application itself, or downloaded to a computer. This allows users to conduct weekly or monthly tests, compare their results and observe any improvements in fitness, which in turn encourages users to carry on exercising due to improvements being observed.

3 Further Work

Through interpretation of the HRM inbuilt Accelerometers it would be possible to calculate user pace, and encourage users to increase it by matching beat of a music track to their own foot fall. It would also be possible to count the number of strides a user takes and with knowledge of their average stride length estimate the distance covered for a workout. The average number of calories burned could then also be calculated and relayed back to the users while exercising. By relaying back this additional information Section 2.3 is further developed by encouraging users to further indulge into physical exercise. The use of the accelerometer data would also make it possible to further accessorise user workouts by introducing specific exercises such as crunches or push-ups verified by the application.

The discussed version of Heart Angel has been designed as a personal assistant to help in the assessment and improvement of personal fitness. But just as data is saved to a mobile phone, it would be easily possible to allow for network data transmission of such data back to GP's. Through the use of 2.5 and 3G technologies it is possible to safely transmit user real-time physiological data after or during workouts over the wireless network for their interpretation and monitoring of GP's [4, 8]. This would help minimise on site patient health monitoring visits and allow users to perform their assessments in whatever location was most convenient for them while relaying progress and results back to GPs.

Finding the time to be able to perform structured exercise, where HR is elevated for long periods of time, is less probable every day that goes by. Our ever increasing busy life styles prevent us from taking much time off, and less people are using such time for exercising. By introducing opportunistic physical activity feedback, incorporation of physical activities into everyday lifestyle to increase the overall level of activity, it would be possible to further encourage users to exercise while going about their everyday lives. By informing users on the total number of steps taken and calories burned in a normal day, it would be possible to encouraged users to further increase their calories burned by, for example, taking the stairs as oppose to an elevators. Natural human competitiveness could then be used to further encourage exercise by allowing comparison of results between users in nearby areas, though data shared should be limited to purely performance data, such as steps taken or calories burned, and not personal such as weight or age [1].

4 Conclusion

With people no longer turning to health clubs as a means of getting and keeping fit but rather choosing to perform their own workouts whenever convenient for them, it is necessary to come up with genuine ways in which to assess, monitor, encourage and promote well being through physical exercise, structured or opportunistic. With mobile phone technology ever improving, and the number of applications we find on these growing, mobiles have become the ultimate gadget for work as well as entertainment. With the development of external health monitoring devices and the increasing connectivity of mobiles it is now possible to pair up such devices to promote personal health.

Heart Angel effectively allows users to convert their already acquired and daily used mobile phone into a mobile personal trainer with the only extra cost of acquiring a HRM. Users can decide to firstly assess their current fitness level against recognised cardio-respiratory tests, and then monitor any improvements to their fitness level at their own convenience carrying no extra gadgets other than their own mobile phone and a HRM. The ability to assess user fitness level through the application allows users to obtain a standardised measure of their current fitness level, as oppose to judging how fit they may be based on their relative performances during workouts, and therefore observe and measure improvements. Heart Angel allows using mobile phone functionalities without any limitations or restrictions so users can listen to their favourite music using their phones inbuilt mp3 player while running the application, as well as making and receiving phone calls.

Monitoring and promoting personal health through the use of technology should not be limited to an economically segmented minority required to purchase the latest specialised equipment. Rather it should be widely available to all that posses a mobile phone that meets a set of basic requirements. The discussed version of Heart Angel does necessitate the use of an inbuilt GPS receiver to obtain location coordinates, but this is not a basic requirement to operate the software and so users can still obtain the maximum health benefit from the application. Not only is the cost of monitoring physical exercise drastically reduced by limiting the number of specialised exercising gadgets users are required to purchase, but users can go round their everyday lives carrying a personal trainer at the touch of a button while using their already purchased, daily used mobile phone.

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Teledermatology Helps Doctors and Hospitals to Serve Their Clients

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Abstract. Telemedicine contributes to efficiency increase and leads to the accelerated development and use of the internet based electronic patient record. The broad use of telemedicine is hampered by rigid decision structures, slow adaptation processes and concern for its consequences. Health Management Practice (HMP) addresses these issues by developing, investigating and implementing telemedicine tools in a modular way. KSYOS TeleMedical Centre, the first virtual healthcare institution in The Netherlands, has successfully applied HMP on teledermatology. Teledermatology has led to high satisfaction and learning effect, 65,1% referral reduction, 40% cost savings, and better quality of care. Teledermatology is an excellent tool for hospitals to dosage their waiting list, increase and strengthen their contacts with general practitioners, and provide them and the patients with better service. HMP has enabled KSYOS to perform over 16.000 teleconsultations, expand teledermatology to other EU countries, as well as to other areas such as teleophtalmology, telespirometry and telecardiology.

Keywords: Health Management Practice, teledermatology, KSYOS.

1 Need for Change in Healthcare Delivery

Increasing pressure on the healthcare sector makes it necessary to design a new model of how to provide care. Without radical changes in the way care is provided, healthcare costs will increase extensively in the coming decades. With a population pressure of 60% at this moment, in The Netherlands, 40% of the population is active to maintain the others, of which one third are older than sixty-five and two thirds are younger than twenty years. In the coming decades, the population pressure will grow to 85% of which half will be over sixty-five and of those a major part will be seventy-five plus. This group is bulk consumer in healthcare. This extensive increase in demand of care will not be followed up by an increase in care providers and care capacity. If the healthcare sector is not going to change, it will probably grind to a standstill. The improved awareness of the need for change in healthcare has as yet not fully led to a powerful introduction of tools that help to improve (the efficiency of) healthcare. Developments in the field of integrated care applications are characterised by fragmentation, and lack of proficiency and marketing insight. The lack of prospect to reimbursement turns investing for parties into a risk. Promising projects remain therefore often on a relatively small scale invisible or just disappear after subsidies are

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terminated. Successful initiatives so far are scarce. However, some are successful. Because integrated services bear many aspects such as healthcare delivery by various care providers, development of software, hosting, research, marketing on the medical market, quality control and negotiations with care providers and health insurers, participants with expertise in the various fields need to cooperate. Successful initiatives are mainly combinations of public and private parties that have the courage to work together, share their knowledge and invest jointly. A requirement for a responsible introduction of integrated services in regular care has proved to be meeting demands for security, connectivity and user friendliness. The Health Management Practice (HMP) model addresses all these aspects.

2 Health Management Practice (HMP)

With the use of Health Management Practice, private and public parties and independent knowledge institutes jointly develop telemedicine tools, study their effect on efficiency increase of the primary healthcare process and empower their modular and subsequent up scaled introduction in regular care. It enables the step by step introduction of new telemedicine tools in day to day care not by weakening it but on the contrary by intensifying it. Health Management Practice consist of four phases: phase I is development and internal testing of a new application or service, phase II is usability research among future users, phase III is efficiency research regarding satisfaction, effectivity and quality parameters and phase IV are implementation studies.

2.1 Phase I: Telemedicine Development

Partners elaborate a telemedicine tool to an integrated service including security, software, hardware, infrastructure, hosting and management. Telemedicine tools developed meet requirements of safety, connectivity and user friendliness. They adhere to national ICT healthcare infrastructures and on the long term add to the development of the electronic patient record.

2.2 Phase II and III: Health Management Research

Health Management Research aims to prove that the use of telemedicine services increases efficiency: brings more satisfaction with users, increased production volume and better quality at equal or lower costs, thus re-routing the dramatic growth in costs in the healthcare sector. It entails usability and efficiency research aiming at professionalising new telemedicine tools in a phased way, obtain support, prove the effect on improvement of efficiency and after that study the user and reimbursement model. Independent scientific parties protocol the various stages of the research and monitor its’ quality and independence.

2.3 Phase IV: Health Management Implementation

All stakeholders – manufacturers, users, policy makers and health insurers – are involved in the design of practice and reimbursement research. Starting point here are significant reductions in costs on a macro level and a healthy business case with surplus reimbursement per use for manufacturers, users and policy makers. The interested parties together establish a price for the use of the telemedicine tool, and predefine performance indicators that are conditional for reimbursement. These performance indicators may entail outcomes on health as well as logistic outcomes. In order to guarantee successful up scaling in regular care, the benefits of the telemedicine instrument for and its synergy with regular care are actively marketed and communicated.

3 Success of Teledermatology in The Netherlands

Health Management Practice has been successfully applied to develop, investigate and up scale teledermatology in The Netherlands. Teledermatology has proven to enable the general practitioner to provide a dermatologist with digital images and short description through a secure internet connection. As both general practitioner and dermatologist experienced teledermatology as enrichment of their work, with emphasis on quality improvement and learning effect, teledermatology has been widely accepted now in regular healthcare. Teledermatology has led to higher volume growth of dermatological care at equal costs in The Netherlands.

3.1 Development: KSYOS Teledermatology Consultation System (TDCS®) as an Integrated Service

Health Management Practice has led to the introduction of the KSYOS Teledermatology Consultation System (TDCS®), through which general practitioners perform teledermatology consultations safely with the use of the unique health worker identification passport (UZI-pas), guaranteeing all patient data to remain confidential, integer and available. This digital pass is issued by the Dutch Ministry of Health. The TDCS® does not only include software, but also the provision of hardware (digital camera, docking station, UZI-pas and card reader), quality monitoring, helpdesk, on site monitoring, billing, administration, education, and malpractice insurance. The expansion of this teleconsultation system to other disciplines has added to the accelerated development of the electronic health record.

3.2 Research: Performance Indicators

In usability studies, the complete service including the infrastructure of the Teledermatology consultation System has been tested under intensive monitoring among a relatively small group of future users (10-20 medical specialists and family doctors) during a short period (4-8 weeks). In these studies software, hardware, logistics and experience of the user have been investigated. Health Insurance companies and policy makers have agreed upon the following performance indicators of Teledermatology that are conditional for it’s reimbursement:

- The use of the Dutch national Unique Health worker Identification pass (UZI-pas),
- Monitoring of the number of prevented physical referrals to the dermatologist
- Monitoring of the response time of the dermatologist

3.3 Unique Health Worker Identification Pass Implementation

On the 1st of June 2007, in total 1732 health workers were working with the UZI-pas; 733 of them have provided by KSYOS for the use of the KSYOS Teledermatology System (43% of all UZI-passes in The Netherlands. This UZI-pas can be use for different other (transmural) services and by other institutions. Teledermatology thus ads significantly to the development of the national health infrastructure and the electronic patient record.

3.4 Number of Prevented Physical Referrals to the Dermatologist

KSYOS has monitored the general practitioner's decision points before and after the Teledermatology consultation. Before the teleconsultation the general practitioner answered the standard question: "Would you physically refer this patient to the dermatologist without the availability of teledermatology?" Afterward the TeleConsult he answered the following question: "Do you refer the patient physically to the dermatologist?" Of 8.863 TeleConsultations evaluated, 71,7% of the population would have been referred to the dermatologist without the availability of Teledermatology (Group A). In 28,3% , this would not have been the case (Group B). In this group, a TeleConsult is asked to for general advise in order to improve the quality of the treatment. After the Teledermatology Consultation, 75,0% are not referred. Of group A (would have been referred without the availability of Teledermatology), 20,9% are referred, a 73,4% reduction. Of group B, (would not have been referred without the availability of Teledermatology), 18% is physically referred to the dermatologist. In the whole population, the total number of physical referrals to the dermatologist decreases from 6.355 to 2.215, a reduction of 65,1%. This reduction includes extra referrals due to advice, quality improvement and potential lowering of the referral threshold. This reduction does not include the long term reduction of referral due to the learning effect of Teledermatology, nor to the advices that have been given in Group B.

3.5 Cost Reducing Effect of Teledermatology

The reimbursement for a Teledermatology Consult is € 69,00. This includes reimbursement for the general practitioner (€ 22,50), dermatologist (€ 20,-) and KSYOS TeleMedical Centre (€ 26,50). The reimbursement for KSYOS includes the complete integrate service. The reimbursement of the general practitioner includes the extra work for Teledermatology Consultation (10 minutes) and all to the TeleConsultation related visits to general practitioner. The general practitioner is not allowed to declare these visits in his regular system. The mean costs of a physically referred patient including treatment are € 275,-. The size of Group A is 71,7% of the total population; the referral reduction is 75,0% in this group). The size of Group B is 28,3% of the total population; in this group is 18% is referred after teledermatology. The cost reducing effect in group A is somewhat reduced by the quality increase in group B, still leading to a cost reduction of 40,0%. The breakeven point for Teledermatology is € 179,02 per TeleConsult. However, due to a long term reduction of physical referral, the cost saving effect of Teledermatology will further increase.

3.6 Service for the Patient: Response Time of the Dermatologist

The trimmed mean response time of the dermatologist was 5.59 hours, the median 3.31 hours. Of all patients 95% received a response within two working days. Most TeleConsultations were sent at the end of the morning of afternoon. This applied also for the response by the dermatologist.

3.7 Perceived Benefits of TeleDermatologie

In interview sessions among patients, general practitioners, dermatologists, hospital management, policy makers and account managers of health insurance companies, Teledermatology was considered to lead to increased service, more working satisfaction, cost saving and higher production volume at equal costs and better quality of care (table 1).

More structured independent qualitative research among 205 general practitioners that work with KSYOS Teledermatology concluded that general practitioners see Teledermatology as enrichment of their work. General practitioners considered Teledermatology to have a learning effect, to be important for their work, to add to the efficiency of the care process, to increase work satisfaction and to fit into their regular work activities (table 2).

Table 1. Perceived benefits of Teledermatology

	Higher satisfaction	Higher production volume at equal or lower costs	Better quality of care
Patient	Answer within 2 days, no waiting list	Accessibility of care in the coming decades, no costs for travelling and absence of work	Quicker and better care, advice in case of non referral, emergencies
General practitioner	Working satisfaction, service to the patient, learning effect, innovation	Extra budgetary income	Learning effect, advices, emergencies
Dermatologist	Working satisfaction, service to general practitioners, increased adherence	Extra budgetary income	Learning effect, more time for more dermatology suited patients
Hospital	Service to general practitioners, increased adherence	Increased adherence to general practitioners, dosage of waiting lists, marketing instrument, free service (no investment for the hospital)	
Policy maker	Innovation	Accessibility or care in the view of the aging population	Quicker better care
Health Insurance Company	Service to clients	Accessibility or care in the view of the aging population	Quicker better care, better service for clients

Table 2. Perceived benefits of Teledermatology by general practitioners

	Fairly positive, positive and very positive
Teledermatology has a learning effect	
I can treat more dermatological conditions by myself	78%
I learn from Teledermatology	83%
Teledermatology is important for general practitioners	
Teledermatology is important in my work	79%
Teledermatology is useful	84%
Teledermatology is efficient	
Teledermatology makes healthcare provision in general more ffective	94%
Teledermatology prevent live referrals to the dermatologists	79%
Teledermatology enables me to service my patients quicker	87%
Teledermatology simplifies the treatment process of patients	86
Teledermatology increases satisfaction	
I like to work with Teledermatology	88%
Teledermatology fits into my routine practice	
Teledermatology adheres to my daily activities	81%

3.8 Implementation of Teledermatology

At this moment, 8.200 general practitioners and 350 dermatologist on a population of 15 million are registered and actively practising in The Netherlands. Eight percent of all general practitioners' consultations concern dermatology. Hereof, 93% are treated by the general practitioner, 7% are referred to the dermatologist, leading to 45 referrals per year. Within the last 1,5 year, KSYOS TeleMedical Centre has connected 1.500 general practitioners and 142 dermatologists. However, 40% of the general practitioners are active in Teledermatology, performing 4.0 Teledermatology.

Consultations per quarter. Overall, all general practitioners perform 0,5 TeleConsultations per month. Despite regular extra budgetary reimbursement for general practitioners and dermatologists, the rapid growth of general practitioners connected is not followed by an equal increase in number of Teledermatology Consultations. In total, over ten thousand TeleConsultations have been performed through KSYOS.

4 KSYOS TeleMedical Centre: The First Virtual Hospital in The Netherlands

Safe, prosperous and socio-economic balanced introduction of teledermatology demands its' provision by certified centers that meet minimal quality requirements and that guarantee reasonable reimbursement of general practitioner and dermatologist, additional to regular reimbursement. KSYOS TeleMedical Centre has been officially recognized as a healthcare organization in December 2005 performing teledermatology consultations. KSYOS contracts health insurance companies that pay for each teleconsultation that is performed. KSYOS in return pays the general practitioners and dermatologists, manages security, software and hardware (digital camera, docking station, UZI-pas and card reader), all logistics and infrastructure with ongoing instruction, quality monitoring and helpdesk function, takes care of invoicing and account management, price negotiating, quality monitoring and liability insurance. It is the information point for (future) parties that certify healthcare service, the logistic process with regards to security and privacy rules and the information process with regards to data storage, continuity and accessibility of information. In this construction, KSYOS is a new business partner for integrated services for health insurers.

Fig. 1. KSYOS TeleDermatology Consultation System

5 TeleDermatology as a Service Tool for General Hospitals

With the ageing and more demanding population, healthcare provision is bound to undergo drastic changes. On regional, national and international level, health workers, policy makers and health insurance organisations are addressing issues of how to keep healthcare accessible for the population in the coming decades despite dramatic changes in demand. Efficiency increase of healthcare delivery and the role of ICT in this process is a recurrent issue in policy documents and grant descriptions. Basic of this efficiency increase is the replacing of the bulk of the work from higher to lower in the health knowledge hierarchy – form medical specialist to general practitioner, from general practitioner to nurse practitioners or from nurse practitioner to the patient – under supervision of the person higher in the hierarchy. Telemedicine is perceived as an excellent tool to achieve this goal, combining innovating techniques, changed working conditions, prevention and education. With the use of telemedicine, conventional general hospitals are able to elaborate on their role as centre of excellence on the top of the knowledge hierarchy in healthcare. On one hand, it enables these hospitals to further focus on highly specialised care as with the help of telemedicine less routine care will come into their boundaries. On the other hand, telemedicine enables these hospitals to maintain their supervising role in “bulk routine care”. In the Dutch setting, KSYOS has taken care of all safety, quality and administrative issues of both general practitioners and has contracted all health insurance organisations for reimbursement. It has therefore enabled hospital to offer this innovative service to their general practitioners and dermatologists without investments, thereby reducing any risk for the hospital.

Apart from the fact that telemedicine in general prepares hospitals for future changes in healthcare delivery, teledermatology has proven to have various immediate positive effects. TeleDermatology enables hopitals and dermatologist to influence their waiting lists. This has been mainly the positioning of teledermatology in The Netherlands: in the growth segment. By doing so, the hospital delivers quicker and better care to general practitioners and patients without cannibalising on their own production. And here is where the second immediate effect has appeared. Teledermatology strengthens the health chain and the contacts between general practitioners and dermatologists. If teledermatology is delivered on a regional basis by a professional institution that stands for safe and user friendly communication, general practitioners and dermatologist are high enthusiastic about teledermatology. By offering teledermatology, the hospital firmly strengthens and enlarges its’ contact area of general practitioners that drain on it. In The Netherlands, teledermatology has proven to be an excellent service tool for hospitals to their regional general practitioners, an issue which has come more and more prominent in the Dutch healthcare system that is planned to be increasingly market driven.

AXARM: An Extensible Remote Assistance and Monitoring Tool for ND Telerehabilitation

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Abstract. AXARM is a multimedia tool for rehabilitation specialists that allow remote assistance and monitoring of patients activities. This tool is the evolution of the work done in 2005-06 between the BCDS research group of UdG and the Multiple Sclerosis Foundation (FEM in Spanish) in Girona under the TRiEM project. Multiple Sclerosis (MS) is a neurodegenerative disease (ND) that can provoke significant exhaustion in patients even just by going to the medical centre for rehabilitation or regular checking visits. The tool presented in this paper allows the medical staff to remotely carry on patient consults and activities from their home, minimizing the displacements to medical consulting. AXARM has a hybrid P2P architecture and consists essentially of a cross-platform videoconference system, with audio/video recording capabilities. The system can easily be extended to include new capabilities like, among others, asynchronous activities whose result can later be analyzed by the medical personnel.

Keywords: Cross-platform, hybrid P2P, XMPP, MS, telerehabilitation, plug-in.

1 Introduction

This paper presents an application to assist medical personnel in telerehabilitation tasks using basic broadband Internet connections and readily available hardware. It is the continuation of the work carried out in the TRiEM project, a joint effort of the BCDS research group of UdG [1] and the Multiple Sclerosis Foundation (FEM in Spanish and Catalan) in Girona during 2005-06 to develop a tool for MS telerehabilitation.

1.1 The Illness

Multiple sclerosis (MS) is a chronic, inflammatory disease that affects the central nervous system. MS can cause a variety of symptoms, including changes in sensation, visual problems, muscle weakness, depression, difficulties with coordination and

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speech, severe fatigue, cognitive impairment, problems with balance, overheating, and pain. MS will cause impaired mobility and disability in more severe cases [2]. The name “multiple sclerosis” refers to the multiple scars (or scleroses) on the myelin sheath (the fatty layer that surrounds and protects neurons, helping them carry electrical signals). This scarring causes symptoms which vary widely depending upon which signals are interrupted.

The prevalence of MS is significant [3]; in equatorial areas it is around 0.0001% while in southern Europe the rate is 6-14 times higher and in northern Europe it is 30-80 times higher. Numbers in North America are on the same range as in Europe.

1.2 TRiEM Project

The prototype [4] developed in TRiEM (Catalan acronym for “telerehabilitation and MS”) allowed medical specialists to carry out patient consults remotely, with the double objective of making a better use of the funds in order to provide longer and more continuous follow-ups and improving the patients’ quality of life.

The system was also designed, at the outset, to use as far as possible standard available low-cost infrastructure; both in terms of computer equipment (CPU, graphic cards, webcams) or communications. For example the prototype can sustain good enough two-way audio and video quality with a basic broadband connection, which in Spain is currently of 1 Mpbs downstream and 300 kbps upstream.

The tool was built on top of an open source instant messaging application [5] and started as a standard videoconference application. In order to adapt it as far as possible to specialist’s necessities and patient's characteristics, additional capabilities of audio/video recording and multimedia management were also included. The prototype used a hybrid P2P architecture (see figure 1 in section 2): a server-centric component for session management, information and remote control messages and a peer-to-peer component for the more bandwidth consuming live audio and video streams.

The application was written in Java and made extensive use of the XMPP open standard [6]. This protocol transmits lightweight, human-readable and easily understandable messages in XML form and it was easily extended for the additional features of the TRiEM prototype. For the multimedia part the Java Media Framework (JMF, [7]) and the Media4j framework [8] were used (the video is sent in H.263 format over RTP). These components allow isolating the application from any specific operating system interface, ensuring that the same application can work in Windows and almost any UNIX-like system.

Although in the end the tool worked as expected, several problems remained unsolved or solved just partially. For one, maintenance of the patient’s computer ended up consuming a significant amount of time and effort. Added to the complexity of the installation and initial configuration, widespread and unassisted deployment of the tool was compromised. Also, while the tool not only covered the initially desired features but minor additions suggested during the testing period, the addition of new features was at least difficult, and in some cases impossible. These issues could not be addressed within the original project’s framework and eventually became the motivation for the work presented in this paper.

As for related work, the field of telerehabilitation has generated abundant literature. For example, already in 2000, Lauderdale and Winters [9] explored the possibility of using then current teleconferencing products for telerehabilitation. In contrast, the American Occupational Therapy Association expressed in 2005 [10] concern about the lack of published research regarding the use of telerehabilitation methods for follow-up of specific occupational therapy services. Nowadays it is still difficult to find telerehabilitation tools that work on more than just one aspect of the rehabilitation process.

The paper is structured as follows: After this introduction, the development and status of the tool is discussed in Section 2 and section 3 is dedicated to the user interface. The paper concludes with the customary conclusions and future work.

2 AXARM: Beyond TRiEM

As mentioned before, adding new features to the original prototype was difficult. Taking into account numerous ideas that arose during the original project it was decided that to achieve the full potential of what was becoming a platform, drastic measures were required. Taking as a starting point the basic plug-in features of the instant messaging application that was used as a base for the tool, we proceeded to a complete refactoring [11] of the application and the development of a full plug-in system.

2.1 Refactoring

The idea of refactoring is to modify the software to make it more amenable to changes without losing or adding new features. As such, a user may not be initially aware of any change between the original tool and the refactored one. Because of that AXARM shares with TRiEM its hybrid architecture (see figure 1 below): The XMPP server allows sessions and passes messages between the parties, while using direct (P2P) connections for more bandwidth intensive data streams (like two-way audio and video streaming).

The refactoring process is progressive: once familiarised with the code it is necessary to identify which parts are to be part of the core of the application and

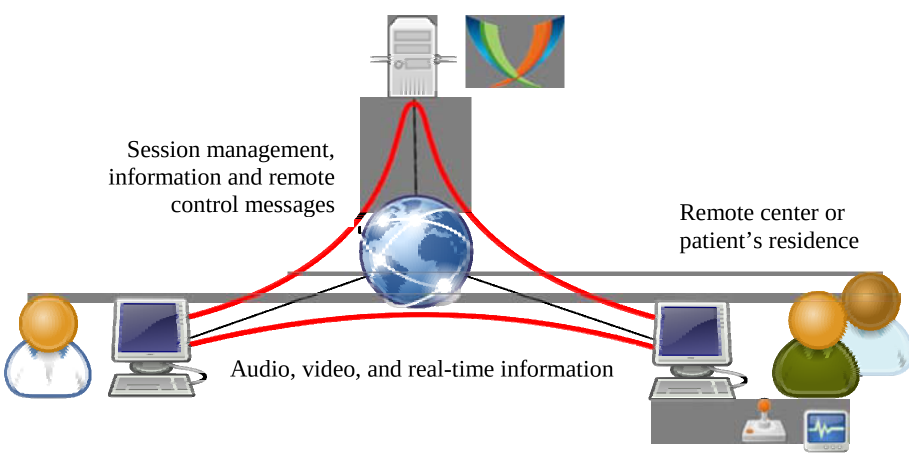

Fig. 1. TRiEM/AXARM common hybrid P2P architecture

which ones will end in a plug-in. Once a feature is part of the core, it is available for all current and future plug-ins. In the end we were able to considerably simplify the development of plug-ins and their access to the application core. As of this writing all of the original prototype's features have been converted to plug-ins (frequently two of them: one version for the patient and another for the medical specialist) and we are working on adding new ones. In the meantime the application has been completely functional with every refactoring improvement and some new plug-ins have been developed. In parallel the application core has been also improved to offer some additional technical features to make plug-in development easier, and the installation and auto-configuration have been simplified as much as possible.

2.2 Plugins

Essentially a plug-in is a file with the extension "jar" that includes the code to run and any additional resources that are necessary (for example, images and sounds). Once a plug-in is part of the system (installing it consists just in putting the file in the application's "plugins" folder) it will be initiated by the application (see figure 2 below). When the plug-in is running it has control of an area of the graphical interface (GUI) as well as access to any XMPP message the application receives (see figure 3 for an example of a message). It is the responsibility of the plug-in to react to those messages it considers its own. This broadcasting behaviour allows different plug-ins to react to general application messages. On the other hand, plug-ins can also use the application core to easily send messages of their own to their counterpart in the application running in another computer.

At first it may seem the plug-in is limited to what the application offers but in fact it can even add its own preference panel to the application "preferences" section to allow easy access to the plug-in parameters. At the same time programming a plug-in results in a much more simple process thanks to the available features via the application core, and only a limited knowledge of the complete application architecture is needed, so the learning curve is quite smooth.

Frequently the plug-ins must be developed in pairs to express the differences between the actions and interfaces available to each role (patient or medical staff). Once a plug-in is ready for deployment, it appears in the general plug-in repository (they can be filtered according to user role) and it can be installed in the application. In fact one of the first steps to implement the plug-in system was to put together our own plug-in repository as the original one (the public repository of the base instant messaging client) is not available anymore.

Currently the AXARM application has plug-ins for almost all of the original features of the TRiEM prototype: *chat*, *recordable videoconference*, *multimedia manager* (to manage A/V recordings), and *notepad* (a simple document viewer/editor). It also has plug-ins that implement new features: *photos* (higher-resolution frame grabbing), *joystick game* (a simple game of motion and coordination control where the specialist sets a difficulty level and see what the patient does

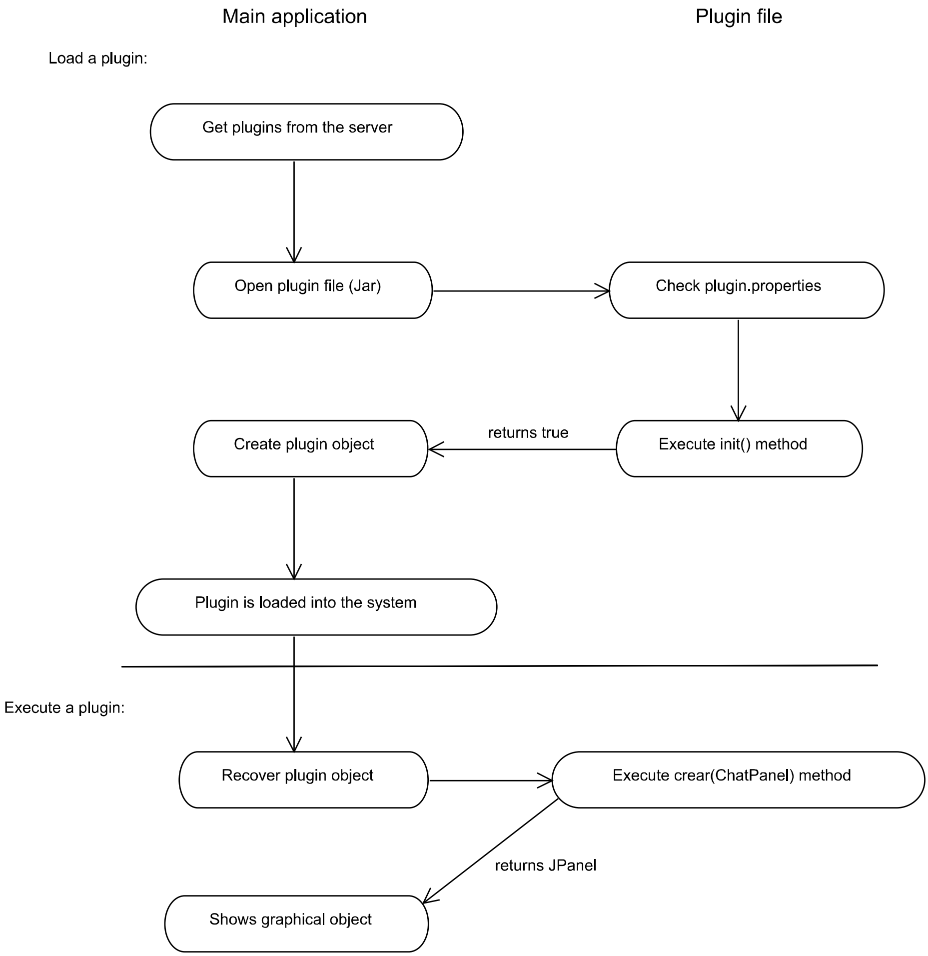

Fig. 2. Interaction between the application core and a plug-in

together with the standard A/V stream) and *offline recording* (where the patient and the specialist can record themselves in order to transfer the recording at a later time).

Both the *joystick game* (figure 3 is an example of its messages) and the *offline recording* plug-ins represent two completely new fields of activities for the application. It is in our plans to explore the use of game control devices to implement new activities that can be carried on remotely. The rehabilitation specialists are especially interested in the use of *dancing pads* for lower-extremities exercises and the possibilities of the Bluetooth-enabled control devices of the Nintendo Wii gaming platform are exciting. The second field of activities is the development of asynchronous activities that the specialist can assign to a patient, the patient can do at the time of their convenience, and the results arrive to the specialist automatically.

```
<message id="zBrbf-7" to="lab1@bcds.udg.edu"
from="lab2@bcds.udg.edu/JBother">
      <xsow xmlns="joysticksession">
            <xdest>32</xdest>
            <ydest>104</ydest>
            <xcursor>123</xcursor>
            <ycursor>250</ycursor>
            <counter>11</counter>
            <squares>0</squares>
            <time>27</time>
            <button>0</button>
            <type>1</type>
            <difflevel>1</difflevel>
            <positions>1</positions>
            <ip>172.26.0.10</ip>
            <reset>0</reset>
      </xsow>
</message>
```

Fig. 3. Example of a XMPP message of the “Patient joystick” plug-in

3 The User Interface

When the application starts the user is presented with the familiar image of a contact roster. The aspect of reusing user previous knowledge and user-friendliness has been important since the beginning of the project. The difference is when a communication window is opened. Instead of just a chat dialog the user is presented with several panels that can be arranged at their convenience either in a single container or in separate windows.

In figure 4 both video panels (local and remote) can be seen with their respective controls, but once deployed the patient’s interface is simplified to the maximum while all the controls remain available to the rehabilitation specialist. The patient side of the *joystick game* plug-in can also be seen on the left of figure 4. Figure 5 shows the specialist side of the *joystick game* plug-in when defining the activity parameters and when the patient is carrying on the game.

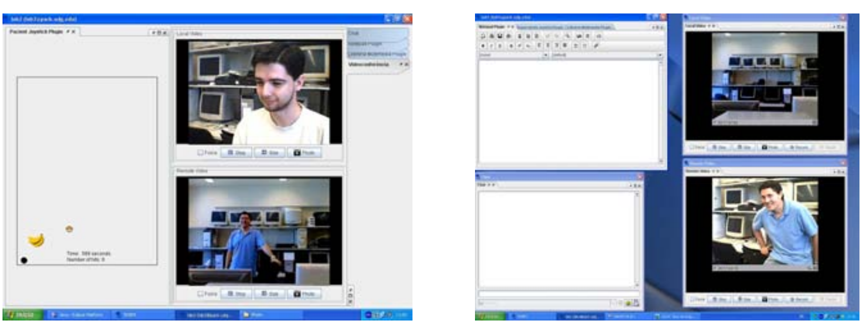

Fig. 4. Graphical interface: personalized panel arrangement

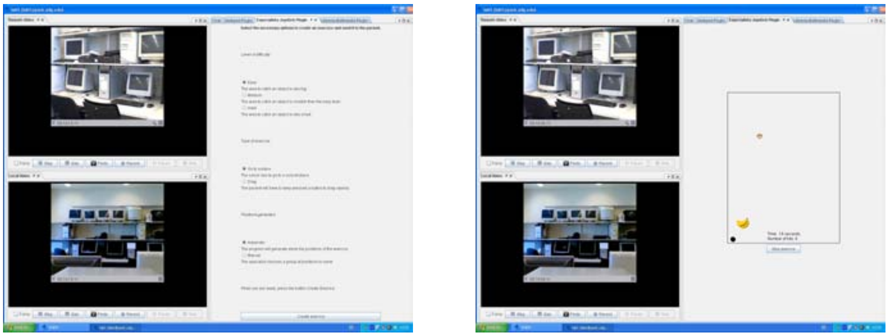

Fig. 5. Graphical interface: *joystick game* for the rehabilitation specialist

4 Conclusions and Future Work

This paper has presented the AXARM application, an extensible tool for remote assistance and monitoring for rehabilitation. A high-level description of the application development as well as specific technical details have been presented, with particular attention to the tool's extensibility and its GUI.

In the short term we plan on developing plug-ins for asynchronous activities, centralise and simplify user management (moving these functions from the application to the XMPP server). We are currently working on the core features to support the asynchronous activities plug-ins. We will also start small scale (10 patients) testing with real patients and specialists.

The incorporation of gaming control devices will follow as well as middle scale testing (up to a hundred patients, possibly involving more than one rehabilitation center) early in 2009, after processing the feedback from the first batch of tests.

As long-term objectives (still without date) we aim to extend the test to several rehabilitation centres along Catalonia. We also want to explore the possibility of packing the system in a standalone appliance for cases where no computer is available or where proper maintenance of the equipment is problematic. For now in these cases we can only install the application in a dedicated Linux partition where we keep administrative rights to ourselves.

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A Group Decision Support System for Staging of Cancer

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Abstract. The TNM classification system was developed as a tool for physicians to stage different types of cancer based on standard criteria, according to a common language of cancer staging. Staging reports are usually performed by oncologists but sometimes are also done by physicians not specialized in this area. In this paper, it is presented a multi-agent system to support group decision that helps meeting participants to reach and to justify a solution. With the increasing use of web applications to perform the Electronic Medical Record on healthcare facilities, this system has the potential to be easily integrated in order to support the medical and clinical e-learning and to improve patient assistance. In fact, the usual need for documentation and specific information by the medical staff can be easily provided by these systems, making a new steep towards a paper free healthcare system.

Keywords: e-Health, Group Decision Support System, Staging of Caner.

1 Introduction

In a healthcare unit, a firm knowledge of specialized areas and their uniform lexicon are required from physicians and other staff, in order to normalize information communication. This necessity is to the need for unambiguous methods when relaying information to others, making perceivable to all the exact meaning of reports and other documents. When dealing specifically with group decision this becomes an even more important factor, as several physicians and other researches with specific thesaurus may be involved. These different backgrounds may result in misjudgments or distortion of information. Considering these facts, several index and norms were created to share among the medical community standard terms of addressing stages, illnesses, symptoms and other technical issues. A common language of cancer staging is mandatory to fully homogenize the flow of information when indicating prognosis, aiding in treatment planning, facilitating treatment stratification and aiding in the analysis and information exchange between different treatment centers for clinical studies [18]. This need for medical staff to share the appropriate nomenclature when reading or receiving a cancer staging report was the driving force that the led ultimately towards the development of an uniform staging system by international organizations. The AJCC (American Joint Committee on Cancer) Cancer Staging

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Manual [1] brings information on staging of cancer at various anatomic sites and incorporates knowledge on the etiology and pathology of cancer.

The staging information is uniform between the AJCC and the UICC (International Union Against Cancer). The Manual contains printable copies of each of the 45 Staging Forms for both individual and institutional use. The Manual remains the essential reference for oncologists, pathologists, surgeons, cancer registrars, and medical professionals worldwide to assure that all those taking care of cancer patients will be trained in the unambiguous nomenclature of cancer staging. Staging is the process of determining how much cancer there is in the body and where it is located. Staging describes the extent or severity of an individual's cancer based on the extent of the original (primary) tumor and the extent of spread in the body. Knowing the state of the disease helps the doctor plan a treatment and determine a prognosis (likely outcome or course of the disease). Staging provides a common language with which doctors can communicate about a patient's case. Knowing the stage is important in identifying clinical trials that may be suitable for a particular patient.

Staging is based on knowledge of the way cancer develops. Some staging systems cover many types of cancer; others focus on a particular type. For most cancers, the stage is based on main factors such as the location of the primary (original) tumor; the tumor size and number of tumors; the lymph node involvement and the presence or absence of metastasis. Different staging systems are used for many cancers of the blood or bone marrow such as lymphoma. Doctors gather different types of information about a cancer to determine its stage. The various tests used for staging depend on the type of cancer. Tests include physical exams, imaging tests (XR, CT or MRI), laboratory tests (blood, urine, fluids or tissues), pathology reports and surgical reports, available in the Agency for Integration, Diffusion and Archiving of Medical Information (AIDA) [2] [3]. There are three different types of staging: clinical staging (based on physical examination, imaging and biopsies), pathologic staging (on patients who gave had surgery) and re-staging (to determine the extent of the disease after a cancer comes back).

The TNM Staging System is one of the most commonly used in Medicine. This system was developed and is maintained by the AJCC and UICC. The TNM classification system was developed as a tool for doctors to stage different types of cancer based on certain standard criteria. The TNM Staging System is based on the extent of the tumor (T), the extent of spread to the lymph nodes (N), and the presence of metastasis (M). Each cancer type has its own classification system, so letters and numbers do not always mean the same thing for every kind of cancer. Once the T, N, and M are determined, they are combined, and an overall "Stage" of I, II, III, IV is assigned. Sometimes these stages are subdivided as well, using letters such as IIIA and IIIB. Stage I cancers are the least advanced and often have a better prognosis or outlook for survival. Higher stage cancers are often more advanced, but in many cases can still be treated successfully. The formal "stage" of a cancer does not change over time, even if the cancer progresses. A cancer that returns or spreads is still referred to by the stage it was given when it first diagnosed. Sometimes, after a period of remission (cancer being undetectable) for certain cancers, if more treatment is planned, a doctor might re-stage the cancer. The same process that was done when the cancer was first diagnosed will be repeated: exams, imaging tests, biopsies, and possibly surgery to re-stage the cancer. If the cancer is re-staged, the new stage will be recorded with a lower case "r" before the re-staged designation. As previously stated, this is not done often. The use of the TNM staging system requires all the staff to bare its current specifications in mind or to search through an immense documentation. The TNM system however is not a static protocol, it is designed to be able to evolve as new discoveries and breakthroughs are carried out in the oncologic area, making it essential to all staff to be updated with new specifications in order to conduct an adequate staging [19]. This difficulty associated to the fact that physicians that are not oncologists may perform staging reports, complicates the use of TNM. Besides slowing down the procedure, it may cause term misjudgment or some incoherence of the staging with the TNM system. Therefore, some mean of helping and hasting the elaboration of the staging report, while at the same time improving their quality is an excellent opportunity for the use of information technologies.

More information in [4].

2 Group Decision Support

Group Decision Support Systems (GDSS) are computer-based systems that aim to support collaborative work, and particularly to increase the benefits and decrease the losses associate to collaborative work [5] [6]. GDSS intend to support collaborative work. We will call “meeting” to all the processes necessary to the completion of a specific collaborative task. A meeting is a consequence or an objective of the interaction between two or more persons [7].

Physically a meeting can be realized in one of the four scenarios: same time / same place, same time / different places, different times / same place and different times / different places. Each one of these scenarios will require from the GDSS different kind of support.

But present group members are not the only persons involved in the process, however it is very common to see a third element taking part in the course of action, the facilitator. The meeting facilitator is a person welcomed by all the members of the group, neutral and without authority to make decisions, which intervenes in the process in order to support the group in the identification of a problem and in the finding of a solution in order to increase group efficiency.

According to [8] a meeting one has three distinct phases: in the Pre-Meeting phase the facilitator prepares the meeting, in the In-Meeting phase the participants will be working in order to accomplish the meeting goals, and in the Post-Meeting phase, it is important to evaluate the results achieved by the group. To model the group formation process it is necessary to establish the steps for the creation of a virtual community of participant agents. The importance of maintaining a community of agents is directly related to the need of obtaining information about their credibility, reputation, as well as their past behaviours.

The selection of agents to participate in a specific group is made from a community of participant agents (AgPs). The agent must be registered for selection. Some information about potential participants should be available in order to allow the acceptance of a particular participant agent by the system:

```
$Agent (Id):: area_of_expertise,
        organizational_factors,
```

interest_topics,
credibility,
reputation,
availability.

where Id, area_of_expertise, organizational_factors, interest_topics, credibility, reputation and availability denote, respectively, the identification of the agent, the set of areas where the agent is an expert, the information about the institution where the agent is enrolled (e.g., employee numbers, production capacity), the interest topics for the agent, the credibility and the reputation of the agent and its availability at a given moment.

The information at the (participant) agent profile is divided into public and private. Public information is supplied by the organization at the time of registration (e.g., area_of_expertise, organizational_factors, interest_topic). At this moment the system does not detain any information about the agent attributes like credibility, reputation (i.e., private information). This information will be determined with more or less detail during the life time of the system [9].

3 The Electronic Medical Record

The Electronic Medical Record (EMR) is a core application which covers horizontally the health care unit and makes possible a transverse analysis of medical records along the services, units or treated pathologies, bringing to the healthcare arena new methodologies for problem solving, computational models, technologies and tools. EMR is the start point for the implementation of Ambient Intelligence in Medicine [14][15]. One aims to develop a comprehensive, structured approach to EMR development and analysis.

The process to collect data comes from Problem Oriented Medical Record (POMR) method [16]. This is a format for clinical recording consisting of a problem list, a database including the patient history with physical examination and clinical findings, diagnostic, therapeutic and educational plans and a daily SOAP (Subjective, Objective, Assessment and Plan) progress note [17]. The problem list serves as an index for the reader, each problem being followed through until resolution.

This system widely influences note keeping by recognizing the five different phases of the decision making process, i.e. data collection, problem specification, devising a management plan, reviewing the situation and revising the plan if necessary. One’s goal is to replace hard documents by electronic ones, increasing data processing and reducing time and costs. The patient assistance will be more effective, faster and the quality of service will be improved [3]. The system uses freeware tools or software database packages, which licenses belong to the Portuguese Health Ministry (e.g. Oracle software). According to the ontology, messages are processed, integrated and archived in large databases. The administrators define the ontology, which can be managed using web tools. The “intelligence” of the system as a whole arises from the interactions among all the system components. The interfaces are based on Web-related front-ends, querying or managing the data warehouse. Such an approach can provide decision support. A context dependent formalism has been used to specify the AIDA system incorporating facilities such as abstraction, encapsulation and hierarchy, in order to define the system components or agents; the socialization process, at the agent level and the multi-agent level, following other possible way of aggregation and cooperation; the coordination procedure at the agent level; and the global system behaviour.

4 The System

The GDSS follows a client-server hierarchy and can be decomposed into four tiers.The first three tiers are responsible for the communication system, while the other one is responsible for the agents monitoring and control. According to the architecture, each agent has an individual and personal role and can interact with the users, answering questions and establishing a dialogue. The users, through web browsers, and mediated by software agents, converse and negotiate with other agents that are able to help the user in a particular area of his interest. This communication is achieved through conveyed messages between users and agents, stored and managed by relational databases.

Using JavaScript, the GDSS allows for a dynamic service that constantly checks in real-time if messages were sent to the user and if whether or not other actions of his concern were performed by any user or agent. This lightweight service runs on an application server that communicates with the database. The XMLHTTPRequest object in JavaScript is used to send and receive commands to and from the server. The messages, the user status, the chat rooms, the buddylist and the blocked users are set and managed by objects following the JSON (JavaScript Object Notation) format and other PHP scripts. The chat rooms allow for users to find the specific agent for their area of interest. The users open these rooms and the agents have permission to act. Chat rooms are spaces for open discussion among users, and places where the agents can be found to perform private tutoring. Personal tutoring allows a better adaptation of the agent to the user's needs and doubts.

With the increasing use of web applications to perform the EMR on healthcare facilities, the GDSS has the potential to be easily integrated in order to support the medical and clinical e-learning and to provide life assistance. In fact, the usual need for documentation and specific information by the medical staff can be easily provided by these systems, making a new steep towards a paper free healthcare system. Moreover, this system allows a better performance of cancer staging, saving time and effort while tutoring the users at the same time. More specifically, the intricacy and length AJCC Cancer Staging Manual can be easily dismembered in its 45 main areas in which the GDSS agents will specialise in and tutor when called for staging a subject with a cancer in that area.

A considerable part of the GDSS backend is developed in JAVA. JAVA is a multiplatform object-oriented language, which proved to offer good performance with most databases, besides allowing the use of several API and middlewares further improving this system.

Agents can exchange information in the same way users can and moreover store and exchange information about their particular expertise areas. These areas are coherent with the protocol underlying in the TNM system. In an analogous way TNM separates staging with a specific tissue and body part, the GDSS uses an agent system that emulate this model increasing performance. Following this line of thought, as an agent asserts the interaction with the user based in its area, it considers if the information that is provided is meaningful to the user. Based on this analysis, it may advise the user a more suitable agent to help him.

The use of these entities in an extensible architecture, allows for the easy adding of more capabilities to the agent and the use of the same methods by different agents. Thereby, an expert agent on a certain expertise area can have its specific behaviour and knowledge and still use the basic methods of communication with the database. This expert agent is designed to be responsible for that specific chat room and that area of expertise. These rooms are created based on the TNM system and oriented to fit the needs of physicians and other healthcare related staff.

The agents have been designed using JADE, the Java Agent Development Framework, which implements in JAVA a Framework that simplifies the development of agents according to the Foundation for Intelligent Physical Agents (FIPA) specifications [20]. The adoption of an ontology that follows the definitions and requirements of AIDA, allows the agents to be integrated with the healthcare environment and opening further opportunities to this agent based system.

5 Conclusions and Future Work

In this paper, a simulated medical practice scenario has been developed for intelligent decision support in the area of staging of cancer.

Decisions about the staging of cancer are taken in the context of a group meeting aiming collaborative work. The system uses agent oriented programming and agents can exchange information in the same way users can and moreover store and exchange information about their particular expertise areas.

The group decision support system emulates the TMN cancer staging system increasing performance and eliminating paper circulation. Information that is provided is meaningful to the user, following the principles of quality, credibility and security. The system advises the user about the most suitable agent to help him and to justify decisions.

Case Based Reasoning (CBR) is the process of solving new problems based on the solutions of similar past problems, but it is also a powerful method for computer reasoning, or a pervasive behaviour in everyday human problem solving tasks.

In future releases, after having a significant set of available classified cases; the system will be upgraded with CBR algorithms. The system will embody dynamic virtual world of complex and interacting populations, entities or agents built as evolutionary programs that compete against one another in a rigorous selection regime, providing a solution to produce the optimal solution to a particular problem, in which its fitness is judged by one criterion alone, the Quality-of-Information.

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A Trust Framework of Ubiquitous Healthcare with Advanced Petri Net Model

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Abstract. Ubiquitous healthcare, which enables patients to access medical services anywhere anytime, is still so immature that particularly trust issues in this area require more researches. In this sense, how to design a trustworthy ubiquitous healthcare system is an interesting problem to be resolved. In this paper, we propose a trust framework for ubiquitous healthcare systems by using advanced Petri net and verify how this trust framework evaluates trust properties when developing ubiquitous healthcare systems. The outcome of the research, the trust framework, can make it easy to understand how trust relationships can be built in ubiquitous healthcare systems via mathematical and graphical models.

Keywords: Trust framework, Petri net, Ubiquitous healthcare.

1 Introduction

As Information and Communication Technology (ICT) is growing rapidly, this technology has been applied to many areas. Healthcare industry has also got benefits from ICT [1]. However, common issues of healthcare industry such as limited budget and resources are still major problems that should be resolved. In this context, one of solutions that have been proposed for healthcare industry is ubiquitous healthcare. Ubiquitous healthcare is anywhere and anytime medical service adopting advantages of ubiquitous techniques such as mobile devices, sensors, etc. Ubiquitous technologies extend healthcare services from hospital-based to anywhere and anytime [2]. Patients, who use this service, send their health information with such equipments. However, as the information is private and contains valuable data, patients may not be willing to use the system even though it provides more convenient way to get healthcare services. Patients, for their trust decision, require the trustworthy information about medical professionals of this service. Therefore, trust has a critical role for using a ubiquitous service [3].

Trust plays an essential role in human life and society. Life without trust is unbearable and chaotic, because anything and everything would be possible [7]. The scenarios presented in [3] show the reason why trust in ubiquitous healthcare is important. In these scenarios, trust provides the decisive basis to make the proper decision among patients, healthcare service providers and resources. Therefore, while designing a ubiquitous healthcare system, we should mention a trust model [4].

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Trust has already been modeled with Petri net in different areas such as e-learning [5]. In ubiquitous healthcare, however, there is a lack of an appropriate model on trust. The contribution of this paper is to propose the basic trust framework for ubiquitous healthcare using Petri net model.

The result of this research is a basic research framework which can be used to study and understand the characteristics of ubiquitous healthcare as well as provide a way how to evaluate and analyze the trust issues when the developers implement ubiquitous healthcare systems. In addition, this framework helps overcome industry limitations such as limited budget and resources as we can see Petri net is currently used for an optimal modeling in various industry areas [6].

Firstly, we define healthcare behaviors according to the scenarios introduced in [3]. Then for mathematical and graphical modeling, we build trust development for ubiquitous healthcare and establish common activities in ubiquitous healthcare by using trust development with advanced Petri net model.

2 Background

Petri net model was created by Carl A. Petri in 1962. Primarily, Petri net was used to study communication with automata but nowadays it is used for modeling, formal analysis, and design of discrete event systems. In particular, as graphical and mathematical tools, Petri nets can be used for automated systems and real-time safety-critical systems because of verifying the model formally. They also have successful cases to model sequence controller [6, 8]. Petri net has not been used only as a process development tool for complex system but also as a mathematical model for reflecting the system behavior [8].

As industry areas are growing, various applications of Petri have been developed, e.g. high-level Petri nets, timed Petri net, fuzzy Petri net, advanced Petri net, Amended Colored Petri net [5, 8, 9]. Especially, advanced Petri net in [5] is introduced for the multi-user collaboration. This advanced Petri net model, in particular, adds the weight of trust rates and reliable factors on Petri net. Thus, this improved Petri net builds trust development in virtual university. Moreover, A Colored Petri net trust model was proposed for public-key infrastructure in [10]. This flexibility of Petri net on trust also makes it possible to apply to the trust development in ubiquitous healthcare.

3 Building Trust with Advanced Petri Net Model

In this section, we define healthcare behaviors based on Petri net approach. The following definition represents the well-formed net for healthcare behaviors concerning trust. For trust development, we use divided nets consisting of healthcare workflow and activities of resources. Each net has the weight of trust rate.

Definition 1. Advance Petri net for healthcare workflow is a well-formed $HBPN = (P, T, A, T_{i \to (i+1)w}, M_0)$; where

$P = \{p_1, p_2, p_3 ..., p_m\}$ is a finite set of places to represent a state in healthcare workflow,

$T = \{t_1, t_2, t_3 ..., t_n\}$ is a finite set of transitions to represent behaviors in healthcare,
$A \subseteq (P \times T) \cup (T \times P)$ is a finite set of arcs such that: $P \cap T = P \cap A = T \cap A = \phi$
$T_{i \to (i+1)w} = range[0,1]$ is the threshold of trust rate from transition i to $i+1$
$M_0 : P \mapsto N$ is the initial marking, where N is a set of nonnegative integers.

Definition 2. Advance Petri net for resources is a well-formed $ARPN^m = (P_r^m, T_r^m, A_r^m, P_{r(i)w}^m, M_{r0}^m)$; where

$P_r^m = \{p_{r1}^m, p_{r2}^m, p_{r3}^m ..., p_{rj}^m\}$ is a finite set of places to represent a state of resources,
$T_r^m = \{t_{r1}^m, t_{r2}^m, t_{r3}^m ..., t_{rk}^m\}$ is a finite set of transitions to represent activities of resources,
$A_r^m \subseteq (P_r^m \times T_r^m) \cup (T_r^m \times P_r^m)$ is a finite set of arcs such that: $P_r^m \cap T_r^m = P_r^m \cap A_r^m = T_r^m \cap A_r^m = \phi$
$P_{r(i)w}^m = range[0,1]$ is the weight of trust rate from p_{ri}^m, the local trust information or score such as the trust or reputation level of resources rated by the patient's cell phone conducting the trust decision mechanism or previous patients and firing is occurred when $P_{r(i)w}^j \geq T_{j \to (j+1)w}$,
$M_{r0}^m : P_r^m \mapsto N$ is the initial marking, where N is a set of nonnegative integers.

Scenarios presented in [3] shows trust considerations as follows: the trust decision mechanism to choose first aid providers between the trust level and time, to provide the medical data according to the trust level of the data requesters, and to choose a reliable service provide based on the reputation rated by previous patient. These factors can be represented by the following definition similar to the way used in trust development in virtual university[5].

Definition 3. The total threshold of trust rate from transition i to j is formulated as follows:

$$T_{(i \to j)w} = \sum_{n=i}^{j} T_{i \to (i+1)w} \quad . \tag{1}$$

The average threshold of trust rate is formulated as follows:

$$avg\ .T_{(i \to j)w} = \frac{\sum_{n=i}^{j} T_{i \to (i+1)w}}{N} \quad . \tag{2}$$

such that N is the value divided the number of arcs from transition i to j as 2.

The total threshold represents the size of trust rate which can be the basis to decide the importance of trust and the average threshold can be basis to decide the density of trust rate.

Definition 4. The total weight of trust rate from P_{ri}^{m} to P_{rj}^{m} is formulated as follows:

$$T_{rw}^{m} = \sum_{n=i}^{j} P_{r(i)w}^{m} \quad . \tag{3}$$

This trust factor has the value between 0 and 1.

The average weight of trust rate is formulated as follows:

$$avg.T_{rw}^{m} = \frac{\sum_{n=i}^{j} P_{r(i)w}^{m}}{N} \quad . \tag{4}$$

such that N is the number of P_{r}^{m}.

The total weight of trust rate shows the flexibility to decide alternatives and the average weight of trust rate is the basis of the possibility for the trust decision e.g. $avg.T_{rw}^{k} < T_{k\to(k+1)w}$ shows the low trustworthy decision.

Graphical trust representation in Petri net is shown as Fig. 1. T_1 and T_2 are transitions to describe behaviors of healthcare such as the aid provider selection and the emergency expedient. T_{r1}^{1} is a transition of activity regarding resources. In this case, T_{r1}^{1} means the decision mechanism based on $P_{r(1)w}^{1} = 1$ and $P_{r(2)w}^{1} = 0.8$. $T_{(1\to 2)w} = 0.8$ represents the threshold which is the minimum value firing P_1 according to the result of T_{r1}^{1}.

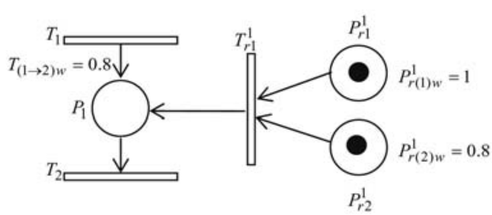

Fig. 1. Graphical representation of trust in advanced Petri net

4 Modeling Trust Framework of Ubiquitous Healthcare

4.1 Modeling Healthcare Behaviors with Petri Net

According to [3], we define healthcare behaviors. Usually, healthcare starts from monitoring a certain person and the monitoring system detects emergency situations. Ubiquitous technologies for healthcare make it possible to understand the emergency situation, make a decision, and communicate with other devices of stakeholders. In this process, various healthcare behaviors are generated. As we mentioned before, *HBPN* is a well formed net to show the mathematical representation of healthcare behaviors and Fig. 2 is a graphical description of healthcare behaviors for the emergency response.

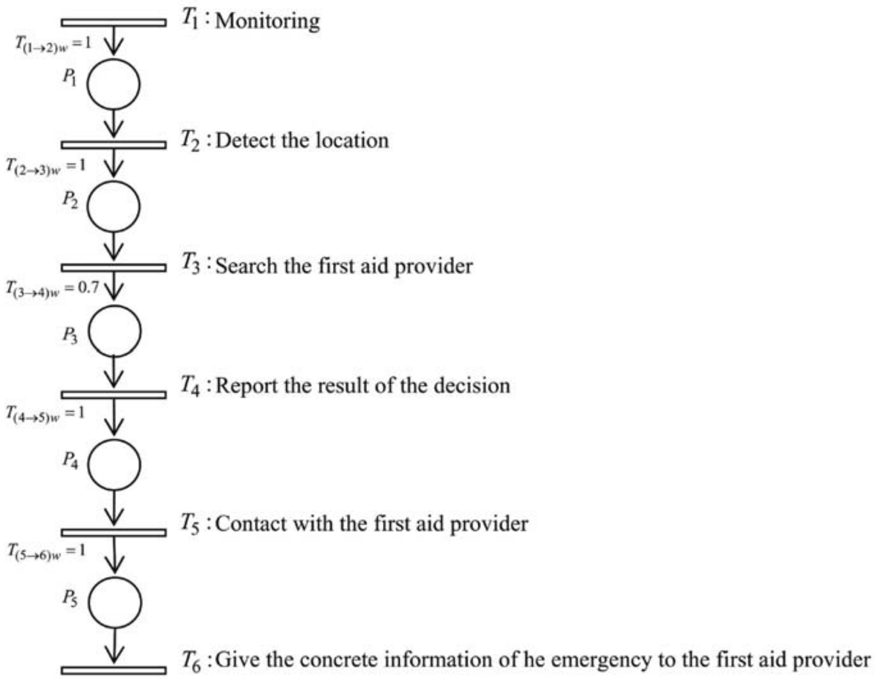

Fig. 2. Emergency response

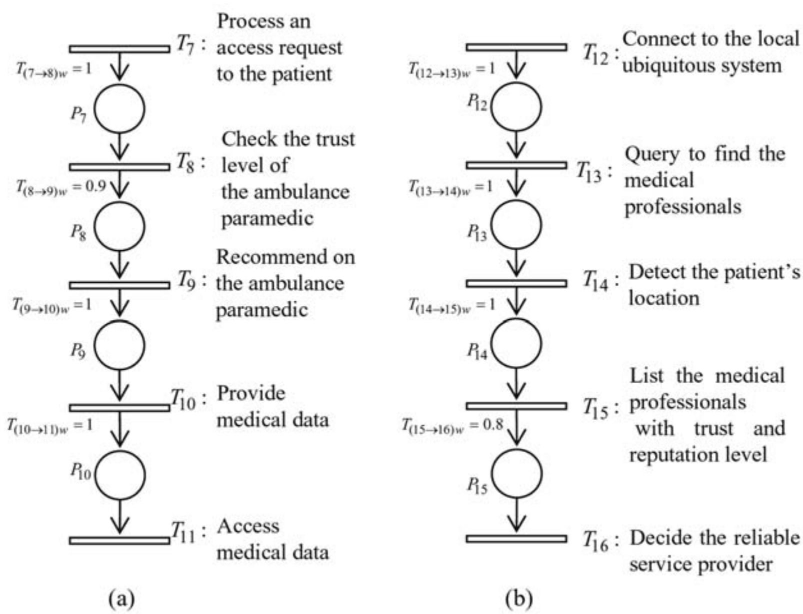

Fig. 3. (a) Access to medical data. (b) Choosing a reliable service provider

Next stage is accessing to medical data of the patient. In this case, after getting help from the first aid provider the ambulance paramedic arriving soon tries to request the permission to access the patient's medical data such as electronic patient record (EPR), and then give the emergency expedient. The aid provider's trust level is used for the decision of accessing data. Fig. 3 (a) shows the detail model of behaviors.

The last trust scenario in [3] shows how to choose a reliable service provider. The patients try to find the physicians with high reputation by their mobile device. They connect to the local ubiquitous healthcare system and query the reputation information from the system. The detail representation is shown as Fig. 3 (b).

4.2 Trust Framework of Ubiquitous Healthcare Based on Trust Activities with Advanced Petri Net

Healthcare trust activities are concatenated with Petri net healthcare behavior model. Fig. 4 shows various alternatives (a set of P_r^3) of the first aid provider. These alternatives have the weight of trust rate which is calculated with trust level and time of them. That is $P_{rw}^3 = \{1,0.6,0.4,0.8,0.5\}$. The trust threshold between T_4 and T_5 is $T_{(3\to 4)w} = 0.7$. In this case, $P_{r(1)w}^3$ and $P_{r(4)w}^3$ is bigger than $T_{(3\to 4)w} = 0.7$ and make P_3 be firing.

In trust activities for access to medical data, we can find two weights. One is for checking the trust level of ambulance paramedic who requests the patient's medical

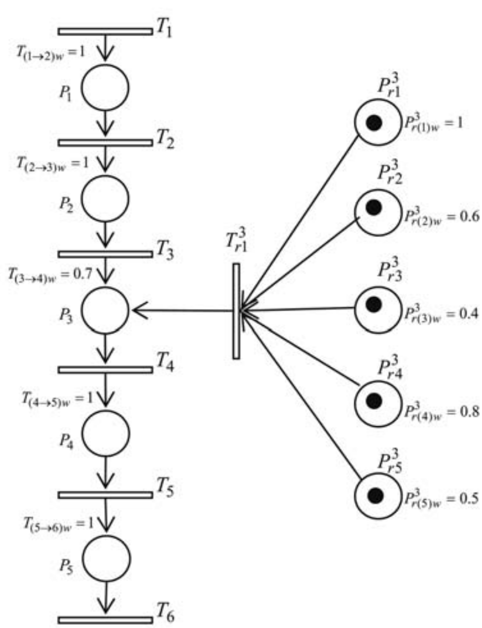

Fig. 4. Trust activity of emergency response

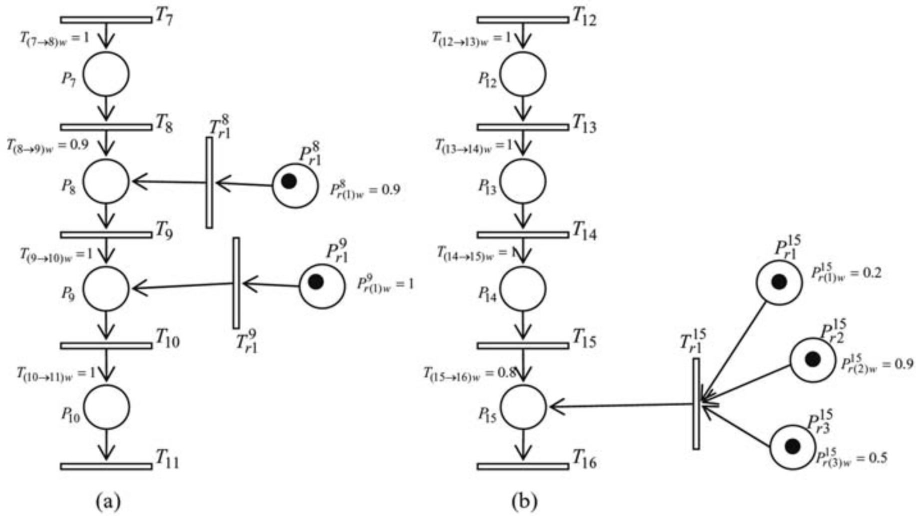

Fig. 5. (a) Trust activity of access to medical data. (b) Trust activity of the reliable service provider selection

data. The other is about the recommendation by the patient's general practitioner. Fig 5 (a) shows the example to permit access of medical data by ambulance paramedic because all weights are more than the corresponding thresholds.

In Fig 5 (b), we can find out the list of the trust weight regarding the reputation of the medical professionals. P_{r2}^{15} has the enough weight of trust and can be the only medical professional decided by the decision mechanism.

5 Conclusion

The problem addressed in this research is lack of an appropriate model on trust in ubiquitous healthcare. We proposed the basic trust framework for ubiquitous healthcare using advanced Petri net model. By determining healthcare behaviors according to the common scenarios, we built trust development for ubiquitous healthcare with advanced Petri net model.

For this purpose, we conducted a quantitative research to define the mathematical relationships between the trust factors and healthcare behaviors. We used advanced Petri net as a mathematical and graphical modeling tool. The trust development built with these mathematical relationships supports the design of the optimal activities among workflow and resources of ubiquitous healthcare.

As a result, the finding of this paper will contribute to implement the trustworthy ubiquitous healthcare system as a promising tool. In addition, this framework helps overcome industry limitations such as limited budget and resources. The future work can focus on enforcing the management method of trust factors as resources.

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PPEPR for Enterprise Healthcare Integration

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Abstract. PPEPR is software to connect healthcare enterprises. Healthcare is a complex domain and any integration system that connects healthcare enterprise applications must facilitate heterogeneous healthcare systems at all levels - data, services, processes, healthcare vendors, standards, legacy systems, and new information systems, all of which must interoperate to provide healthcare services. The lack of interoperability within healthcare standards (e.g. HL7) adds complexity to the interoperability initiatives. HL7's user base has been growing since the early 2000s. There are many interoperability issues between the widely adopted HL7 v2 and its successor, HL7 v3, in terms of consistency, data/message modeling, precision, and useability. We have proposed an integration platform called PPEPR: (Plug and Play Electronic Patient Records) which is based on a semantic Service-oriented Architecture (sSOA). PPEPR connects HL7 (v2 & v3) compliant healthcare enterprises. Our main goal is to provide seamless integration between healthcare enterprises without imposing any constraint on existing or proposed EPRs.

Keywords: HL7, SOA, Web service, Semantic and Interoperability solutions.

1 Introduction

The average patient going to hospital presumes that no matter where he/she goes, that every specialist has access to his/her complete medical record. This is sadly not the case. Instead, in a hospital with 40 departments there will exist at least 40 specialist electronic patient record systems, some or all of which may exist in isolation. To enable interoperability between these systems the IT department typically has to employ a software programmer to develop interfaces between those systems. The proliferation of interfaces approaches n^2 where n is the number of EPRs in a hospital environment. In many cases this programming task not achievable and the result is the movement of paper files between departments which have perfectly functioning IT systems. HL7 is the most widely used standard the transfer of messages between EPR systems, which helps in reducing the amount of software development to be done in order to make EPRs interoperable. HL7 v2 is the version most commonly used, while HL7 v3 has been released as a standard since 2003. HL7 v3 adoption has been slow to date, but this is improving as newer EPR systems are developed and installed.

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2 PPEPR: Plug and Play Electronic Patient Records

In PPEPR our focus on HL7 is due to the fact that it is the most widely used message based healthcare communication standard. In the HL7 Standard, there are two major versions, HL7 v2 & v3. While the HL7 v2 standard was created mostly by clinical interface specialists, the v3 standard has been influenced by medical informaticians. HL7 v2 messages are unstructured and flexible involving optional fields and segments whereas HL7 v3 is structured and provides greater consistency across the entire standard. HL7 v3 has published Web-service[1] and SOA4HL7[2] profiles to support healthcare workflows and benefits from interoperability features offered by Web service technologies.

Web services provide the technology foundation for implementing and delivering service-oriented architecture (SOA) platforms. However, a clear development methodology is missing and "gaps" between HL7 and Web service and SOA artifacts exist. The two core challenges of conventional computing - search and integration - (also known as "semantic gap" of SOA) are not addressed by SOAs [1-3]. Therefore, SOA itself is not a complete solution for the integration of information systems. The integration and/or interoperability requirements of information systems have resulted in the development of new breeds of SOAs, called semantic Service-oriented Architecture (sSOA). The "semantic gap" between HL7 versions and SOA-HL7 artifacts are solved by using ontologies-An ontology is a specification of a conceptualization [4]. The ontologies are used in the context of SOAs to resolve ambiguity in data, service and process definitions. We have introduced a functioning EPR integration platform in [5], called PPEPR: Plug and Play Electronic Patient Records. In this paper, first we analyse HL7 from the EPR integration perspective and benefits of PPEPR over existing integration solutions. Secondly, we briefly describe the PPEPR's semantic Service-oriented Architecture (sSOA) and types of integration it supports. Then we present a example scenario that briefly explains how PPEPR integrates heterogeneous EPRs. Next, we briefly explain how healthcare message, service, and process definitions are semantically annotated, grounded and mediated. Finally, we explain PPEPR assessment that shows PPEPR's effectiveness which is evaluated on various integration parameters.

3 HL7, EPR, and PPEPR

One of the issues with HL7 v2 is that it is not a structured standard and EPR vendors were given the flexibility of interpreting the standards. This resulted in many EPRs implementing variations on the standard, thus reducing interoperability. In the cases where HL7 v2 is used, engines are employed to ease the integration burden. These HL7 engines are used to map between these non standard implementations. HL7 engines do work between HL7 v2 systems but suffer a number of drawbacks: (1) Significant manual effort (2) initial set up is expensive, and (3) it creates a maintainability problem. By using HL7 engines hospital IT departments are replacing the n^2 interface development problem with an n^2 mapping problem. Replacing or

[1] http://www.openhre.org/local/HL7WSP_August2003.doc
[2] http://www.hl7.org/v3ballot2008jan/html/infrastructure/soa4hl7/soa4hl7.htm

upgrading one EPR system will mean the reimplementation of n sets of mappings. (4) HL7 engines currently in use mostly cater for EPR systems implementing HL7 v2. They will not cater for systems implementing HL7 v3.

PPEPR can work as a standalone product directly interfacing with EPR systems or can be used as an add-on to existing HL7 engines. The PPEPR software consists of two parts: The Design-Time and the Run-Time. The design-time portions of the system are used when installing PPEPR and configuring the various EPR systems which are to be made interoperable. The benefits of PPEPR over existing offerings are:

Semi Automatic: The work involved in modelling the environment into which PPEPR will work is semi-automatic. The only manual effort to be done during the design time is validating the internal representations of the messages and web services involved in the workflow. The operation of PPEPR is completely automatic.

Flexible: PPEPR allows the easy addition and modification of models reflecting the changing environment within a hospital. Upgrading an EPR system from HL7 v2 to one which uses HL7 v3 is no longer a problem. Once the models are created then new system can be incorporated into the hospital without any additional software development.

Robust: With the hub-and-spoke topology inherent in using PPEPR the system is more robust than a peer-to-peer topology more typical of a system-by-system integration effort. Allied with the hub-and-spoke topology is the suite of models built for use with PPEPR. These models are built at a conceptual level and are more resistant to change than the low-level mapping functionality available with other systems.

HL7 v2 and HL7 v3: As noted above PPEPR will seamlessly cater for HL7 v2 and v3 EPR systems.

4 PPEPR's sSOA for EPR Integration

As discussed above, healthcare is a complex domain, comprising vendors, standards, legacy systems, and information systems which differ inherently from one another. PPEPR provides a unique approach to interoperability. The core solution lies in enabling semantic interoperability between existing and new EPR systems. PPEPR is based on the design principles of a semantic SOA Reference Architecture[3] and is built around semantic Web service technologies [Web service execution environment (WSMX), Web service modeling language (WSML), Web service modeling toolkit (WSMT)[6-8] and the conceptual framework, the Web service modeling ontology (WSMO)]. The details of semantic Web service technologies are outside the scope of this paper. The PPEPR architecture considers three types of integrations between EPRs based on their Web service capabilities (or lack thereof) [5].

1. EPR (HL7 v2) (non-Web service) ↔ EPR (HL7 v2) (non-Web service).
2. EPR (HL7 v2) (non-Web service) ↔ Web-Service enabled EPR (HL7 v3)
3. Web-Service enabled EPRs (HL7 v3)

[3] http://www.oasis-open.org/apps/org/workgroup/semantic-ex/

5 Example Scenario

This section presents an example scenario described in figure 1, which consists of six messages including the request for a patient's lab test, lab test result, response, and confirmation messages.

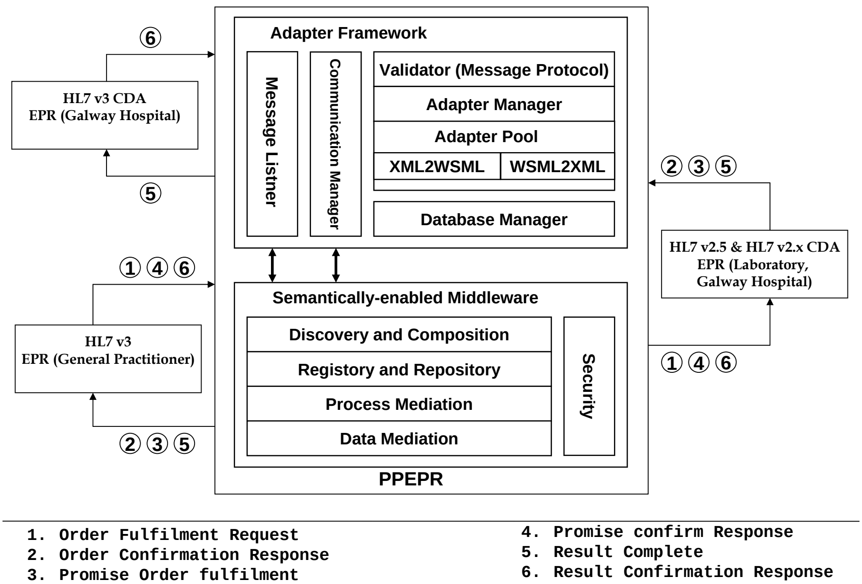

Fig. 1. PPEPR Architecture and Lab Test Order Use Case

EPR System, General Practitioner (GP): This EPR is HL7 v3 compliant and it places a Lab test order fulfilment request to another independent EPR system [hospital laboratory].

EPR System, Hospital Laboratory: This EPR is HL7 v2.5 and HL7 v2 Clinical Document Architecture (CDA) compliant. The hospital Laboratory receives the order for patient's lab test results from HL7 v3, HL7 v2.x, and HL7 v2/v3 Clinical Document Architecture (CDA) compliant EPRs.

EPR System, Galway Hospital: This EPR is HL7 v3 CDA (Clinical Document Architecture) compliant and receives lab test result from HL7 v (2.x, v2/v3 Clinical Document Architecture) compliant Hospital Laboratory.

Each actor has a specific 'application role' [e.g. Order Placer as General Practitioner (GP), Order Fulfiller as Hospital Laboratory, and Result Receiver as Galway Hospital and General Practitioner (GP)] and PPEPR acts as an integration platform. Figure 1 shows the significant elements of the PPEPR conceptual architecture. Starting from the bottom up, Web service execution environment (WSMX) [i.e. semantically-enabled middleware] is the primary engine which allows PPEPR to mediate upon the messages being transferred between heterogeneous EPR systems. WSMX uses the Web service modeling language (WSML) as the internal representation of the Web services and messages. The first step in the run-time use of PPEPR is lifting the incoming XML and EDI messages from EPR systems to their semantic definitions. This lifting process is performed within the adapter framework which transforms XML messages to their internal WSML representations. Once the message is represented in WSML, PPEPR can then mediate upon the message using the Data Mediator. The design-time components of PPEPR are used during the configuration of existing EPR systems. This involves schema level integration (grounding and ontology mapping) of the messages to be exchanged. As noted in the next section much of this work is automated, and what manual work remains is the verification of the modelled messages. Currently PPEPR can process messages in two formats [EDI, XML]. In PPEPR, semantic service (WSML) and process (sBPEL[9]) definitions are developed at design time where grounding(WSDL to WSML and back) and invocation of services are performed by the semantically-enabled middleware (WSMX).

6 PPEPR Assessment

The following parameters are used to measure the impact of Semantics within PPEPR and effectiveness of PPEPR as an integration platform:

1. **Design-Time**
   - (a) *Modeling HL7 message:* The time taken for modelling HL7 ontologies, creating transformation rules (e.g. XSLT), and mapping definitions takes on average 1.5 days. A typical HL7 engine takes 0.5 days for mapping (syntactic). Similarly, PPEPR also takes 0.5 days for mapping (semantic). Therefore, extra work using PPEPR is 1 day for ontological modelling. The measurement was based on developers-recorded observations with good level of knowledge in HL7 and semantic technology tools. Each message within HL7 v3 consists of 49-51 ontological concepts. Each message within HL7 v2 consists of 36-40 ontological concepts. On an average 102 mapping rules are required between ontological concepts of two equivalent HL7 v3 and v2 messages. Approximately, 230-245 types of messages are contained in each version of the HL7 standard.
   - (b) *Syntactic vs. Semantic Mapping:* Syntactic mapping is predominantly based around the XML/XML Schema level of expressivity. Due to the inherent nature of XML/XML Schema, mappings are more at an implementation level and that causes a significant increase in amount of mappings. In PPEPR mappings are at the semantic(ontological) level which by nature maps two equivalent elements (concepts) at a

higher level. The results have shown that the number of mappings reduced by up to 50 percent-PPEPR's major milestone.

2. **Run-Time**
   (a) *Execution-time:* The total message exchange time [message transformation, mediation and transmission] measured between two EPRs on typical broad-band connection is 2-3 seconds.
   (b) *Transformation:* During the first stage of PPEPR development we tested the correctness of message transformation. The purpose of this test is to ensure that transformation (lifting/lowering) process is not losing the original message content and structure.
   (c) *Stability:* In the last 2 months 190 messages has been exchanged on a PPEPR prototype with 100 percent success rate.

3. **Commercialization Potential**
   PPEPR can work as a standalone product directly interfacing with EPR systems or can be used as an add-on to existing HL7 engines. The PPEPR software consists of two parts: The Design-Time and the Run-Time. The design-time portions of the system are used when installing PPEPR and configuring the various EPR systems which are to be made interoperable. The outputs of the PPEPR project are fourfold:

   (a) *The Software:* Components, which aid in the automation of many tasks associated with modelling of the system, are included with PPEPR. The run-time software which adapts and mediates upon the messages is also included.
   (b) *Modelling:*
      i. Ontologies: HL7 v2, HL7 v3, and HL7 v3 & v2 CDA
      ii. Mappings between Standards: Segments and Fields, Data Types, and Vocabularies
   (c) *Modelling Process Description:* This is a key component of our project and is focussed on easing the handover of the technology to companies who wish to license PPEPR for use either as is, or as part of an existing product set.
   (d) *Return of Investment (ROI) Measurement:* We are making significant efforts to measure the benefits of PPEPR. At this point in our development we have automated most parts of the design-time operation and have fully automated the run time portions. We have measured the resources it takes to model messages and get them operational in PPEPR. Work remaining here relates to comparing that effort to that required to use traditional methods. We are also cognisant of the knock-on benefits of using PPEPR in any environment, where the models created for data mediation can subsequently be used in other contexts to potentially allow Case Based Reasoning.

7 Related Works

COCOON[10][4] **& ARTEMIS[10,11]**[5] are 6th Framework E.U projects aimed at setting up semantics-based healthcare information infrastructure and developing semantic Web Services based Interoperability framework for the healthcare domain. The major differences between the eHealth projects described above and PPEPR are:

- PPEPR requires no changes to existing EPRs.
- Other projects are Web-scale projects. The major focus of PPEPR is to ease the integration burden of healthcare enterprises. Additionally, PPEPR's architecture is flexible enough to include Web-scale integration.
- PPEPR architecture is flexible enough to integrate the Web service enabled EPR (HL7 v3) and the traditional EPR (HL7 v2).

RIDE[6] **& SemanticHEALTH**[7] are E.U roadmap projects with Special Emphasis on Semantic Interoperability. PPEPR has been influenced by the **RIDE & SemanticHEALTH** guidelines to design and develop a *semantic* solution to a core eHealth interoperability problem.

8 Conclusion and Future Work

PPEPR is of immediate benefit to healthcare organisations wishing to integrate their Electronic Patient Records systems. The PPEPR running demo[8] shows the messages exchanged between actors of the above defined example scenario. We have used the growing field of semantics within IT to produce a system capable of mediating between heterogeneous systems. We are in the process of validating our software within a clinical setting and the output of this will be an evaluation of the methodologies and technologies used throughout PPEPR. This will give us direct feedback on the use of PPEPR and will fuel further development of the product. Next steps for PPEPR already identified include the addition of functionality to mediate upon heterogeneous healthcare processes. This means extending beyond the individual messages to the "conversations" within which those messages are exchanged, so that clinical processes can be executed in a manner consistent with the EPR systems supporting the clinicians. Secondary uses of PPEPR relate to its use in clinical decision support and enabling guided navigation of patient records represented by semantically modeled messages. PPEPR will also provide a means to integrating telehealth applications into the healthcare enterprises, by accepting sensor readings and by using PPEPR to mediate upon those reading. We can provide sensor-integration with existing HL7-compliant EPR systems. We will also focus on further easing the transfer of this new technology into environments unfamiliar with semantics.

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[4] http://www.cocoon-health.com/
[5] http://www.srdc.metu.edu.tr/webpage/projects/artemis
[6] http://www.srdc.metu.edu.tr/webpage/projects/ride/
[7] http://www.semantichealth.org/
[8] http://www.ppepr.com/

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VirtualECare: Intelligent Assisted Living

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Abstract. Innovative healthcare projects are arising in today's society, normally presenting as major advantage the reduction of care provider's costs. Being these advantage a legitimate one, we are trying to take it a step forward through the use of proactiveness, decision making techniques, idea generation, argumentation and quality, not only of the in transit information, but also of the provided service as well. With these objectives in mind, the VirtualECare project was born. In this paper we are going to briefly present the project and make a position of the actual developments in this first year of work.

Keywords: e-Health, Ambient Intelligence, Assisted Living, Active Ageing.

1 Introduction

Once the human population is progressively ageing, it matters that the elderly in need of special attention, is growing. Old age brings new problems (e.g. entertainment, health, loneliness), aggravated with the lack of specialized human resources to assist their necessities. Besides that fact, one may point out, for example, that pressure exists in government and society (e.g. budgetary restraints, cost of medical technologies and cost of internment) that will force readjustments of actual entertainment and/or health care practice, which may also affect other co-related public systems [1, 2].

This work looks at the role that inter-organization cooperation and learning plays within the innovative processes of a smart home for care of the elderly, and, suggests a framework that allows a set of organizations to strategically model a collaborative environment that is conducive to innovation. The major idea is to enhance elderly quality of life, allowing them an "active ageing", thus being able to participate in social, economic, cultural, spiritual, civic and family affairs, physically and labor, remaining active contributors to their families and communities [1]. The path to pursue, in order to achieve the presented idea, relies on a mix of different sensibilities from Artificial Intelligence, such as Decision Trees and Automated Learning, coupled whit different computational paradigms and methodologies for problem solving, such

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as Agent Based Systems and Group Decision Support Systems [3], thus being able to achieve a high level of "intelligence" in what may be denominated as "Smart Healthcare Homes" [4].

1.1 Contextualization

In the last years we have assisted to a proliferation of various research projects in order to increase the quality of care services and reduce the associated costs, especially the ones that require the patient to be delocalized from his natural habitat (Home). Normally these tend to be simple and basic reactive alarm systems without many requirements from the support platform point of view [5-7]. In our opinion these systems were very useful to delineate a path for others to follow. Taking this path we have presented the VirtualECare project [8, 9] which we believe will be the next generation of remote proactive healthcare system with, in our case, Group Decision techniques for problem solving.

2 Application Scenario

The main goal of VirtualECare is to improve end user's quality of life allowing them to enjoy the so-called active ageing. To achieve this purpose we will take advantage of the enormous evolution new technologies have assisted in past years.

To better understand the amplitude of VirtualECare, let's consider the following scenario [10]:

"John has a heart condition and wears a smart watch that takes his blood pressure three times a day. His watch also reminds him to take his medications and the proper dosage for each medicine. If anything is unusual, his watch alerts both him and the Group Decision Support System (GDSS). John also has a PDA that contains an interactive health control table where he can monitor his medications, schedule his exercises, manage his diet and log his vital statistics. The GDSS has access to this table so they can keep up to date on his condition. Currently, John's watch detects that his blood pressure is unusually high. The GDSS receives a grade B and calls him to check what might be causing his high blood pressure (diagnose). At the same time John receives a checklist of possible causes to review. John compares this list to his own health control table in his PDA to see what might be wrong. Meanwhile, the GDSS decides John should come to an appointment.

Later on, Laura is at home and decides to phone her dad. During the VoIP phone call she realizes he isn't looking very well. She decides to review his Electronic Clinic Process and comes to her attention that dad's has being having high blood pressure. However she also realizes that VirtualECare GDSS already has being alerted and is already taking care of it. Laura can know relax, and don't annoy dad with health questions."

The presented scenario requires an infrastructure to support all the several intervenient and provide basic interaction mechanisms. On top of this infrastructure an extensive number of services can be deployed and/or be developed.

3 VirtualECare

The VirtualECare is an intelligent multi-agent system not only to monitor and to interact with its costumers (being those elderly people or their relatives), but also to be interconnected to other computing systems running in different healthcare institutions, leisure centres, training facilities or shops. The VirtualECare [9] architecture is a distributed one, being their components unified through a network (e.g., LAN, MAN, WAN), and each one with a different role (Fig. 1).

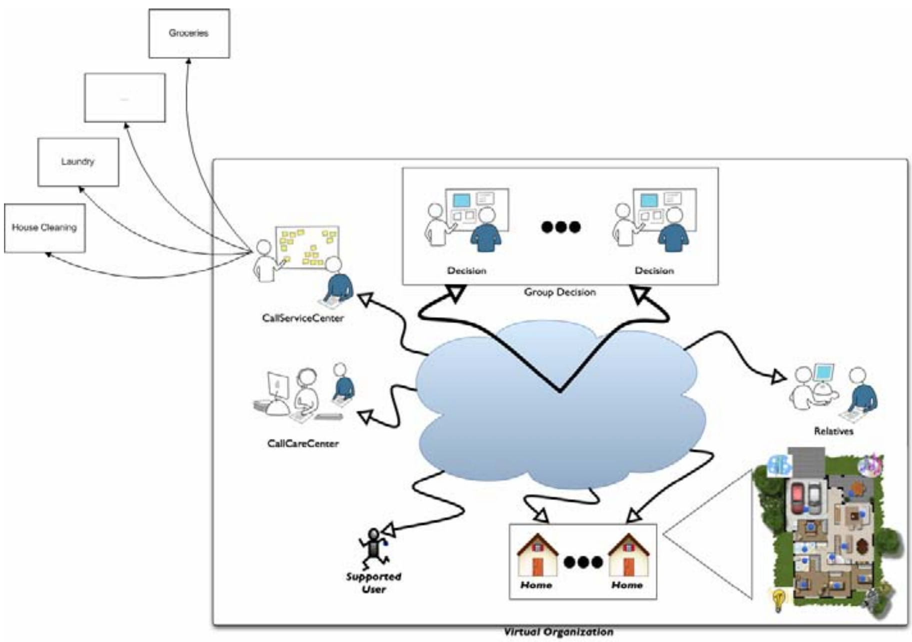

Fig. 1. VirtualECare

SupportedUser* –** Patient with special healthcare needs, whose critical data is sent to the ***CallCareCenter and forwarded to the ***Group Decision Supported System***;

Home* – *SupportedUser natural premises. The data collected here is sent to the ***Group Decision Supported System*** through the ***CallCareCenter,*** or to the ***CallServiceCenter***;

***Group Decision* –** It is in charge of all the decisions taken at the VirtualECare platform. Our work will be centred on this key module;

***CallServiceCenter* –** Entity with all the necessary computational and qualified personal resources, capable of receiving and analyze the miscellaneous data and take the necessary actions according to it;

***CallCareCenter* –** Entity in charge of the computational and qualified personal resources (i.e., healthcare professionals and auxiliary personnel), capable of receiving and analyze the clinical data, and to take the necessary actions.

Relatives SupportedUser - Relatives which may and should have an active role in the supervising task of their loved ones, providing precious complementary information (e.g., loneliness).

In order to the Group Decision Support System take their decisions, one needs of a digital profile of the SupportedUser, which may provide a better understanding of his/her special needs. In this profile we may have different types of data, ranging from the patient Electronic Health Record to their own personal experiences and preferences (e.g., musical, gastronomic). It will provide tools and methodologies for creating an information-on-demand environment that can improve quality-of-living, safety, and quality-of-patient care.

3.1 Infrastructure

Considering the above scenario, and the needs it implies, we have designed a first proposal of a generic, configurable, flexible and scalable infrastructure as presented in Fig. 2. It is expectable that on top of it an extensive number of services will

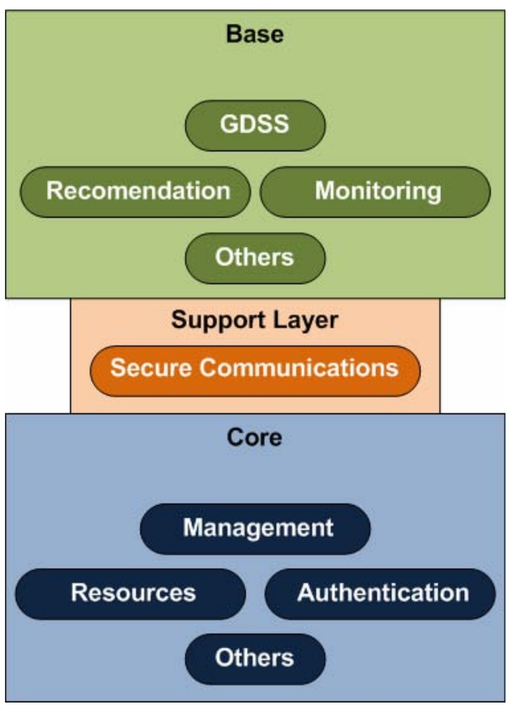

Fig. 2. VirtualECare Infrastruture

progressively arise. These services must, and are being, developed as Web Services, thus allowing the coexistence of several, different, software languages interacting with each other through the use of common messages.

The fundamental components of the proposed infrastructure are:

- *Secure Communications* – in order to all the components interact, a secure communication infrastructure is mandatory;
- *Management* – responsible for configure and monitor the involved components;
- *Resources* – responsible for every component registration and manage the resources catalog;
- *Authentication* – every component must authenticate itself in order to be able to interact with others;
- *Recommendation* – responsible to make problem solving recommendations;
- *Monitoring* – responsible for interacting with all the sensors and report its results to the GDSS;
- *GDSS* – responsible for Decision Making.

4 VirtualECare Simulation Environment

Simulation consists of creating an alternative reality to represent a real object. When making a simulation, generally one expects to predict how a given object or system behaves in the real world. This way, it is possible to draw conclusions about the behaviour of the system being studied and about its feasibility without having to actually build the system. It is very important to select the most important characteristics or behaviours of the system to simulate so that the results are as accurate as possible. These parameters to select may comprise not only the object being simulated but also the environment that surrounds the object. In the last years, this technique has grown a lot mainly thanks to advances in computer systems performances. Simulation is used to model complex systems that are either too expensive or too dangerous or simply impossible to assemble in the real world due to its characteristics. Some of the common uses of simulation are the modelling of natural systems (e.g. weather forecasts, storm evolution, and earthquake damage), testing and optimizing new technologies, and the construction of new or special buildings (e.g. the new skyscrapers, dams).

The VirtualECare project represents a complex infrastructure and architecture, so it is advisable to create a simulation environment that allows for the system to be tested and assessed before a real life deployment. In our case, we clearly need to study the behaviour of the system when specific cases occur, ranging from the reactive cases (e.g. react to a temperature change) to the more complexes (e.g. there is no movement in the last room the person was spotted for a long period of time) [11]. We also want to know what will happen in cases of malfunctioning in some components or if all the alarms went on at the same time. This is in fact one of the main advantages of simulation: it enables us to study specific scenarios that can hardly occur but are possibilities, without having to face the consequences of them really happening. We are therefore using simulation for studying the behaviour of the several project components and improve them before all the equipment is acquired.

Our simulation consists of a house with four rooms, the environment around the house and the user itself. When implementing this, the first step was to select which parameters to simulate. We have already acquired the 1-Wire temperature and luminosity sensors and this data does not need to be simulated. However, the rest of the components and/or sensors are being simulated to ensure that we have an “as real as possible” environment. We are, therefore, simulating the movement, humidity, fire, flood and gas alarm, the vital signs of the user which comprise the heart beat rate, the body temperature and the blood pressure and an outside weather station. In the actuators side, we are simulating all kinds of home appliances, ranging from an oven or a coffee machine to the lights or HiFi.

A major decision that we took was to develop all our simulation using OSGi and R-OSGi bundles [11-13]. This means that the current architecture and logic organization of the components is the same that the final system will have. By doing so, we expect to fasten the last phase of the development of the project since we will only need to replace the generation of the simulated data by the real components. The rest of the system remains the same and has already been hardly tested, which gives us great confidence on the performance of the final system. It is therefore clear that the simulation occurs only in the generation of the data from the sensors and in the state of the appliances.

5 Conclusion

In this paper we briefly present the VirtualECare project and make a position of its recent developments. We also present how, thru simulation, our idealized platform and architecture is already able to monitor a patient and his respective natural habitat. This is our initial approach to a potential resolution that we are now trying to take a step forward thru the built of a functional prototype in a central Portuguese Hospital to make the necessary real life tests in order to adequately fundament our project or make the necessary adjustments.

Because of our simulation platform, we were already able to improve and make some adjustments to our infrastructure and respective architecture before its full implementation, making us more confident on the future behaviour of our prototype.

However we are yet only addressing, through simulation and eventual deployment, a very small part of the amplitude of the project. In parallel we are also idealizing, and in some case implementing, the remaining component and joining our efforts to give all of them the needed proactiveness (e.g.: GDSS, CallCareCenter, CallServiceCenter and Relatives) [8, 9, 14].

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Privacy and Access Control for IHE-Based Systems*

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Abstract. Electronic Health Record (EHR) is the heart element of any e-health system, which aims at improving the quality and efficiency of healthcare through the use of information and communication technologies. The sensitivity of the data contained in the health record poses a great challenge to security. In this paper we propose a security architecture for EHR systems that are conform with IHE profiles. In this architecture we are tackling the problems of access control and privacy. Furthermore, a prototypical implementation of the proposed model is presented.

1 Introduction

The Electronic Health Record (EHR) represents the lifelong, time and location independent collection of all healthcare related information for a citizen stored in electronic form [8]. To realize EHR systems two distinct approaches can be applied: either a central management system can be used to store the whole healthcare data in one repository, or a distributed approach. In the distributed approach healthcare data will be stored within the internal information system of the health institution that creates them. The IHE initiative has adopted the second approach and developed integration profiles that define how current related standards can be implemented to realize distributed EHR systems.

This work is an approach to tackle access control and privacy issues in distributed EHR systems that leverage IHE profiles. We are proposing a security architecture and a prototypical implementation in the context of the Health@net project. The Health@net project [8] develops the core components of an eHealth system in accordance with IHE integration profiles.

The rest of the paper is organized as follows: in section 2 we present related work. Brief background is introduced in section 3. The security and privacy requirements are defined in section 4 and our proposed security architecture is discussed in section 5. Finally we present our prototypical implementation in section 6 before we conclude in section 7.

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2 Related Work

Issues around privacy and access control in ehealth systems have been covered extensively in the literature [3, 6, 9, 21] and security requirements were defined for ehealth systems [5, 7]. Compared to these work, we have identified security requirements in special cases of distributed HER in the context of systems leverage IHE profiles. Furthermore, we propose a suitable security model that fits the adapted system architecture.

The only related work, to our knowledge, that consider security and privacy in IHE conform systems are done by Namli et al. in [18, 19]. They propose an approach to realize IHE privacy and authentication profiles using XACML and SAML. While we tackle the privacy issue as well, we identified the drawbacks of the privacy profile and the challenges related to the distributed nature of EHR in IHE systems. Accordingly, we propose a general access control and privacy related security model that goes beyond the capabilities of the proposed IHE profile(s). Within this model we offer a suitable solution for the identified drawbacks.

3 Background

3.1 Integrating the Healthcare Enterprise (IHE)

To realize the goal of EHR, the *Integration the Healthcare Enterprises* (IHE) initiative was launched in 1999 [11]. IHE defines *Integration Profiles* for a variety of systems [14]. Ten of the integration profiles are assigned to the IT infrastructure technical framework. These profiles specify the interactions and the interfaces between various healthcare applications and the messages exchanged using well known standards such as HL7 and DICOM. To address the interoperability problem in sharing electronic healthcare records, Cross Enterprise Document Sharing (XDS) profile was developed. The XDS IHE integration profile [10] assumes that these enterprises belong to one or more affinity domains. A *clinical affinity domain* is a group of healthcare enterprises that have agreed to work together using a common set of policies and share a common infrastructure. This profile does not define specific policies and business rules, however it was designed to accommodate a wide range of such policies to facilitate the deployment of standards-based infrastructures for sharing patient documents. This is managed through introducing a registry/repository architecture for storing the medical information and their metadata. Figure 1 shows the XDS-IHE repository/registry architecture diagram. The following distinct actors with separate responsibilities can be identified:

- The *Document Repository* is responsible for storing documents in a transparent, secure, reliable and persistent manner and responding to document retrieval requests.
- The *Document Registry* is responsible for storing meta information about those documents so that the documents can be easily found, selected and retrieved.

– The *Document Source* is the producer and publisher of documents. It is responsible for sending documents to the *Document Repository* entity and providing the *Document Registry* with the metadata.
– The *Document Consumer* queries the *Document Registry* for documents meeting certain criteria, and retrieves selected documents from one or more Document Repositories.

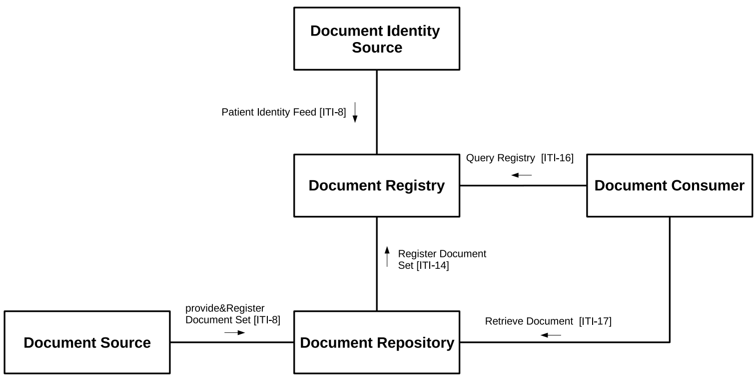

Fig. 1. Cross-Enterprise Document Sharing diagram

3.2 Access Control

According to the architecture proposed by ISO [1], the access control enforcement engine consists of two main functions: the *Policy Enforcement Point (PEP)*, and the *Policy Decision Point (PDP)*. An access request is received by the PEP. PEP queries the PDP about the access decision of the received request. According to the decision rendered by the decision point the PEP permits or denies the access to the target.

Different standards and policy languages have adopted this architecture and extended it with some additional functionalities. For example, the XACML based enforcement engine in [17] includes additionally a *Policy Administration Point (PAP)* and a *Policy Information Point (PIP)*. PAP is the entity that creates, stores, distributes and manages policies. PIP on the other hand is considered as the source of information needed to make decisions.

4 Security and Privacy Requirement

Based on access control and privacy requirements mentioned in IHE profiles [12, 13], the data protection regulation in Austria[1] and previous scientific study of security requirements in eHealth systems [8] we can summarize the following main requirements:

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[1] http://www.ris2.bka.gv.at/Bund/

1. In the electronic Healthcare data exchange, each healthcare provider must be assigned a specific role which must be authenticated using an electronic certificate (e.g stored in the e-card).
2. Healthcare providers are only allowed to access healthcare documents they need according to the roles they were assigned. The mapping rules between different roles in healthcare paradigm and document types they require were formulated by law- and medical- experts in a set of guidelines called *Rule-Base* For example a user of the role *pharmacist* requires only documents of type *prescription*.
3. Doctors are allowed to access the healthcare documents that they create.
4. The identifiable healthcare data for specific patient is only allowed to be used under the consent of the patient for specific purpose.
5. The patient should be able to access all documents in his personal healthcare record.
6. Additionally to the general *Rule-Base* rules, the patient should be able to control the access to his personal record, i.e. defining who is allowed to access all or parts of the documents in the record, like the family doctor.

5 Design Model

The distributed nature of EHR and policy language requirements pose some challenges to the design of the access control system for IHE systems:

1. Two different kinds of rules must be enforced by each request to the health record: The rules representing the *Rule-Base* guidelines and the patient's personal preferences.
2. The EHR must be considered as one virtual single resource when users with full rights are accessing it. For example, if the patient is trying to get access to the complete EHR, checking his right to use each single document alone means a great overhead. Hence the access right in this case must be checked once and applied for all documents.
3. Requests to use a set of documents of the EHR for users without full rights must be processed once by the PDP. Patient's EHR consists of various document, each is considered one resource object. Nevertheless, decisions for this set of documents must be taken only once to avoid the resulting overhead.

5.1 Policy Types

As mentioned in section 4, two kinds of rules must be enforced by the access control system: the rules that represent the *Rule-Base* guidelines and those defined by the patient representing his personal preferences. Consequently, the system must support two kinds of security policies: standard access control and privacy policies.

Rule-Base rules define the rights each role in the healthcare paradigm should be assigned to: Role Based Access Control (RBAC) model [20] is to be adopted for the standard policies [3]. On the other hand, the rules that the patient defines to allow specific users to access his record for specific purposes is a privacy policy. Privacy in the healthcare domain and its policy characteristics have been analyzed in the literature [21] and defined by the OECD guidelines [2]. One of the most important elements of a privacy policy is the *Purpose*. It states the purposes for which the information will be used as specified by the patient.

5.2 Decision Making Process

Decision making process is divided into two phases: the first phase will be initialized from the requesting domain and considers EHR as one resource. The second will be initialized from the different responding domains and considers each document in the EHR as single resources.

- *Phase one*: when users with full access rights (like the patient himself or the trusted family doctor) are trying to access the whole EHR, then processing the request based on single documents and in various affinity domains causes an avoidable overhead. This overhead can be reduced by (1) launching the decision process from the requesting side, before the request is distributed to the various responding affinity domains and (2) conceiving the EHR as one virtual resource by the PDP. Thus, we introduce the first decision making phase at the requesting side considering the EHR as one single resource.
- *Phase two*: is useful for normal users with no full access rights (like the specialist in the motivating example). When such users try to access multiple documents of the EHR, PEPs in the responding domains should make multiple decision requests for multiple resources. Consequently the PDP will make multiple decisions. To meet this challenge, access control system must support single decision requests with multiple resources. Thus the overhead caused by accessing multiple resources can be alleviated. In this case all requests for the whole EHR or multiple documents will be processed only once by the *PDP* and the decision(s) will be rendered once document-wise. The decisions of this phase will be called in this paper *Multiple Decision*.

5.3 Security Architecture

Considering the dual policies used, the multiple-resource request supported and the two phase decision making process we conclude the security architecture depicted in Figure 2.

It shows our proposed security architecture with a two-step decision making process and two types of policies to meet the security requirements illustrated in section 4 and the challenges aforementioned.

First of all, the *Enforcement Point* in the requesting side *(Req_PEP)* sends a decision request to the central PDP. The PDP considers the whole EHR as one virtual resource, and checks whether the user requesting the EHR is allowed to get access to it as a whole or not. In case of a *permit* response, the *Req_PEP* asserts the decision to all responding domains and no further checks are carried out. In case the requesting subject is allowed only to access parts of the EHR, then the *Req_PEP* will forward the request to the responding domains. The *Enforcement Point* of each responding domain sends a muli-resource decision requests to the PDP. In both decision steps the PDP gets the corresponding policies of both types from the *Administration Point* (PAP).

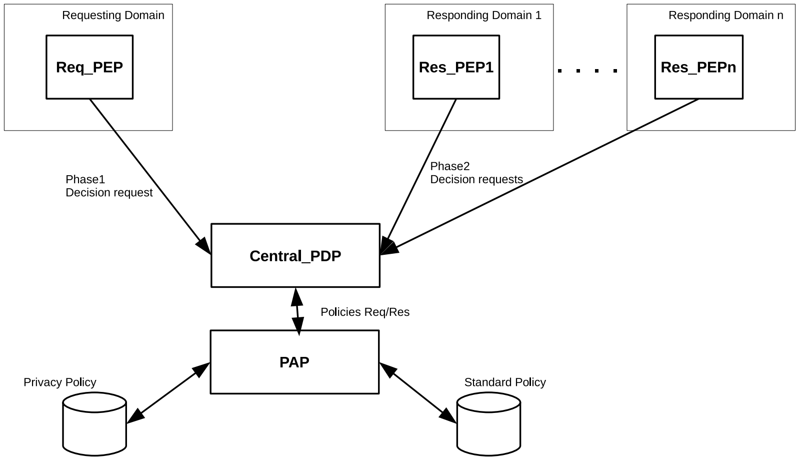

Fig. 2. Design model of the security architecture

6 Prototypical Implementation

In this section we present a practical implementation of our security architecture for systems leverages IHE profiles (especially XDS profile) using XACML as a policy language.

Figure 3 shows the prototypical implementation architecture. The system consists of one requesting affinity domain (A) (represents to the institution from where the user is making the access request) and multiple responding domains (B and C), where the documents of specific patient's EHR are stored. We are assuming the general case where the requesting and responding domains are different. When the user sends a request through the *Document Consumer* in the requesting domain the following steps will be executed:

1. First of all the user will be authenticated using the *Identity\&Attribute Provider (IP)*. The IP authenticates the user, checks his identity using the e-card system in Austria[2], and finds out his assigned role.
2. The checked identity and the assigned role will be rendered as SAML attribute assertion to the *Document Consumer*.
3. After being authenticated the enforcement point of the *Document Consumer* launches the first phase of the decision making process. The PEP sends a decision request to the PDP at the central administration entity.
4. The PDP in this phase checks whether the user has a full right to access the EHR as one resource. This is done by requesting the corresponding privacy policy of the patient and search for permit rules with target of the form

```
<subject category=access-subject> userx_id </subject>
<subejct category=owner-subject> patientx_id <subject>
<resouce> any </resource>
<actoin> read/write </action>
```

[2] http://www.chipkarte.at

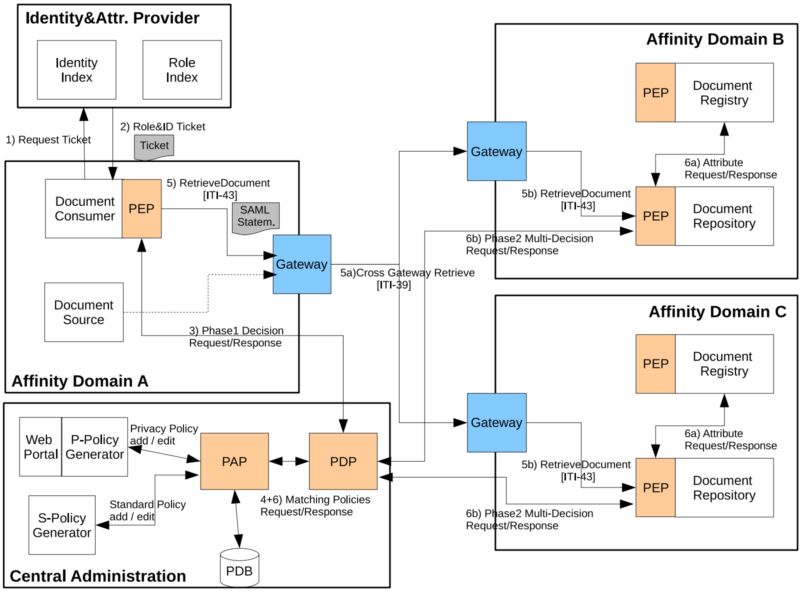

Fig. 3. Security Architecture

This rule shows whether the user *userx_id* is allowed to read or write all documents of the patient with the Id *patientx_id*.

5. If the decision is permit, the user (*userx*) is allowed to read/write the complete EHR of the patient (*patientx*). In this case the requesting PEP will forward the request to the affinity domains containing the EHR documents of the patient with a SAML decision statement. The PEPs in the responding domains will enforce the decision contained in the SAML assertion, i.e. permit access to all documents belonging to the patient *patientx*. Hence, no further checks are carried out. However, if the response contains a *NotApplicable* decision, which means that this rule is not applicable and the user has no full right. Therefore finer decision must be made on the document basis.
6. For finer decision, the requesting PEP forwards the request to the responding domains with attribute SAML statement containing the *Id* and the *role* of the requesting user. Consequently, all PEPs attached to the corresponding document repositories will launch the second phase of the decision making. This is done by sending *multi-resource* requests to the central PDP[4]. The PDP in turn fetches the related standard and privacy policies from the *Policy Administration Point (PAP)* and makes the multi-decision accordingly. Finally the PDP renders the response(s) to the responding PEPs to enforce them.

The complexity of the policies used requires security experts to create such policies. This raises serious difficulties in using these policies in real application, where normal users, like the patient, or non-security experts, like the system administrators, have to generate the policies. To lessen the burden of creating and handling complex XACML policies, we are proposing two kinds of policy generators in our prototype. *Details about the policy generators are described in an accompanying paper [15]*.

7 Conclusion and Future Work

In this paper we present our work to develop and implement a security architecture that tackles access control and privacy requirements of distributed EHR applications in the context of systems leveraging IHE profiles. Furthermore a prototypical implementation is developed and tested in a real eHealth, IHE conform application.

The documents that are released to doctors are no longer monitored and controlled. However, some security requirements demands the document be monitored and controlled [16]. To tackle this problem usage control and obligation models were proposed. These models are to be investigated in the healthcare domain in the future.

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An Avatar-Based Italian Sign Language Visualization System

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Abstract. In this paper, we present an experimental system that supports the translation from Italian to Italian Sign Language (ISL) of the deaf and its visualization through a virtual character. Our objective is to develop a complete platform useful for any application and reusable on several platforms including Web, Digital Television and offline text translation. The system relies on a database that stores both a corpus of Italian words and words coded in the ISL notation system. An interface for the insertion of data is implemented, that allows future extensions and integrations.

Keywords: Sign Languages, Computer Graphics, Virtual Reality, E-Inclusion.

1 Introduction

Providing deaf people the possibility to follow and understand TV, Media information, and entertainment channels is a significant step toward their inclusion in the global community and it may be considered a natural evolution of a process started by computers, internet, and mobile phones. The integration difficulties of persons who were born deaf or got deafness in the first years of life are higher because they could not acquire the knowledge of the spoken language.

Sign Languages allow deaf children acquiring a full cognitive development within their community composed of hearing and deaf persons.

Such cognitive development represents the prerequisite to a full access to the education, the culture and the inclusion in working and social environment. An increasing request for ISL interpretation in educational, legal, and healthcare context is foreseen and soon expected to be extended to the culture and entertainments. The depicted scenario makes clear the relevance of the availability of low cost system to cover, in a sustainable way, the increasing demand for a wide range of services including ISL contents.

The present paper presents a system aimed at supporting deaf people in different contexts by displaying sign language gestures through a visual character, hereinafter referred to as “avatar”. In particular, the paper mainly focuses on the sign language

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synthesis via a parameterization of the avatar gesture starting from an ISL intermediate form.

In section 2 a state of the art of this technology is presented. Section 3 exploit the architecture of the system. Section 4 gives an insight on the characteristics of the ISL grammar and how can be formalized. Section 5 describe the structure of the ISL gestures and how can be elaborated. Section 6 depicts the implementation of a database for ISL translation. Section 7 gives an overview of the graphical engine adopted in our project, whereas section 8 concludes the paper, outlining future improvements.

2 State of the Art

Several projects targeted Sign Language synthesis and significant results have been achieved to improve accessibility of the deafs to the hearing world.

The VISICAST project defined the architecture for sign language processing and gesture visualization by an Avatar [1]. VISICAST brought to the eSIGN project [2]. Additional examples of complete systems are BlueSign (University of Siena, Siena, Italy) [3] and TESSA (University of East Anglia, Norwick, UK) [4].

Most of the recent research activities focused on the creation of characters for video games and the definition of Avatars acting as virtual assistants. The Avatar animations are either synthetic or based on motion-captured data (MoCap). The former ones brought to the definition of several animation languages [5], while the latter ones offer today very reliable systems (e.g., VICON [6]). The main drawback of these systems is that they implement a translation system from the source language to the target signed language. This translation is difficult for the deaf to be understood, as the output language does not follow the rules of the sign language for the deaf.

3 System Architecture and Organization

The architecture of the overall system is in Figure 1.

The system takes, as input, written sentences in the Italian Language and provides, as output, their representation in the *Italian Sign Language*, resorting to the gesture of a virtual character (avatar), generated by a proper graphic engine.

Input Italian sentences are first translated into an intermediate form, the so called "*ISL sentences*", by an *Italian to ISL translator*. The translation phase can be accomplished in several ways, ranging from automatic machine translation, statistical and/or rule-based, to purely human manual translation, in case supported by ad hoc Assisted Editors. In some cases the translation can already be available and stored in proper databases.

The translator, regardless its actual implementation, must rely on a formally defined *ISL sentence grammar*.

ISL sentences are then parsed and analyzed by a *Graphic Engine Command Generator*, charged of generating the commands to be provided to a *Graphic Engine* to enable it to properly display the movements of a virtual character (avatar). These movements obviously represent the representation, in the ISL, of the original Italian sentence. The selected Graphic Engine is a commercial one, originally designed for

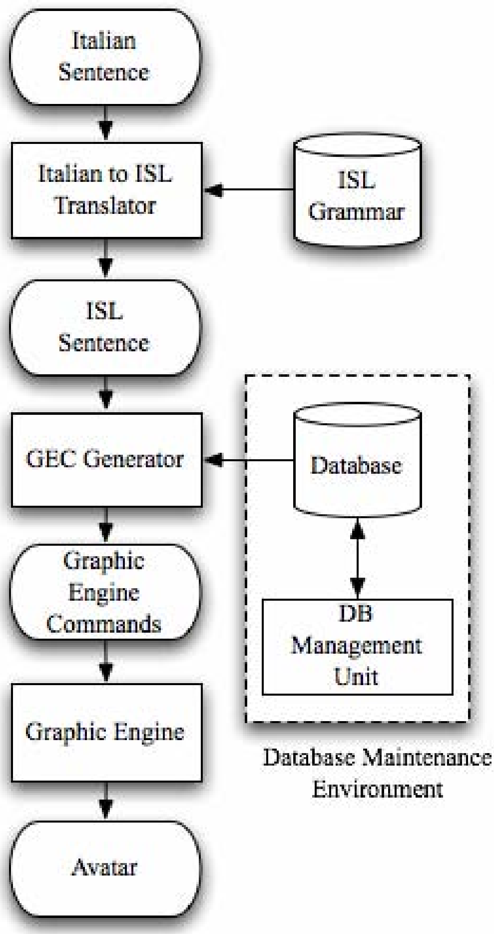

Fig. 1. System Architecture

the translation and visualization of American Sign Language gestures [7]. The tool offers a high level of realism in performing movements and commands can be expressed in an XML format.

The command generation phase strongly relies on the information items stored in a Database, including, among the others, Italian words, words representation in ISL Notation and the commands for the target avatar, represented as XML files.

In the sequel of the paper we shall focus on the various components of the system reported in Figure 1.

4 ISL Sentence Grammar

The visual communication modality that characterizes sign languages brings to an extremely different morphology with respect to spoken languages, and gives them more flexibility. For example the signer realizes the concordance in genre and number arbitrarily by placing the words in the space or by making the concordance by the time. Thus, two signs can be made contemporarily and have a concordance on the basis of the same time in which they are signed.

An additional important ISL feature is the presence of *classifiers*, also used in the spoken Chinese language. Classifiers are signs used to mark the concordance between elements in the sentence. They do not identify an object, but a category of objects with respect of their shape or the way in which they are grabbed; more in general, they express the *type* of an object, such as “animal”, “thin object”, “round object”, etc. They are mainly used in locative sentences but can be found in other constructs, as well. For instance, in the sentence “the ball is on the table” an interpreter will perform the “ball” sign with the left hand, and then the “table” sign with the right hand. Then she/he will sign the classifier for the round objects (the ball) above the classifier of the square surface (the table). Both the classifiers are made with the right hand. By moving one classifier above the other, she/he expresses the concept of “to put on”.

Other general features of ISL include, for instance, the extensive use of personal pronouns to distinguish between inclusive and exclusive forms, as in the spoken Maori language, and the absence of defined and undefined articles, as in the Latin language.

In addition, proper names are usually finger spelled, whereas words non belonging to the basic ISL (such as, for instance, most of technical and medical terms and neologisms) must be expressed resorting to sentences expressing an equivalent semantic.

A formal *regular* grammar has been defined to represent ISL sentences. Resorting to a Backus-Naur Form (BNF), it is expressive enough to catch all the above mentioned distinguishing features of ISL sentences.

5 ISL Gestures

In ISL, as in any other sign language, several parameters are needed to properly characterize each gesture [8]. In the implementation of our system, the following parameters have been adopted:

1. *Configuration*: The form taken by the hands in the gesture
2. *Place*: The point in which the hands forms the gesture
3. *Orientation*: Position of the palm of the hands
4. *Movements*: The way in which the hands move
5. *Non-manual components*: Other movements or characteristics of the gesture such as eyes, torso and head movements.

By varying just one of these components one can create signs that slightly differ each other and that are usually referred to as “Minimal Couples” [9].

The existence of Minimal Couples is exploited during the command Generation phase.

The serious issue of how representing the set of “signs” of the Italian Sign Language has been solved resorting to the Radutzky Italian Sign Language Dictionary [10]. It gathers all the words actually present in the Italian Sign Language and represents a de-facto standard for the deaf community in Italy.

The dictionary provides a corpus of Italian words and the description of the corresponding sign by means of a picture. In addition, each sign is notated with the so called "*Radutzky Notation for ISL (RNFI)*", i.e., a sequence of symbols that codes the first 4 classes of parameters listed above (non-manual components are not included in the RNFI notation.

Figure 2 shows an example of RNFI. Each word is represented by:

1. a "base": a set of symbols coding hand configuration and orientation,
2. an "exponent", which codes the movement and provides information about the part of the body that the hand touches during the sign.

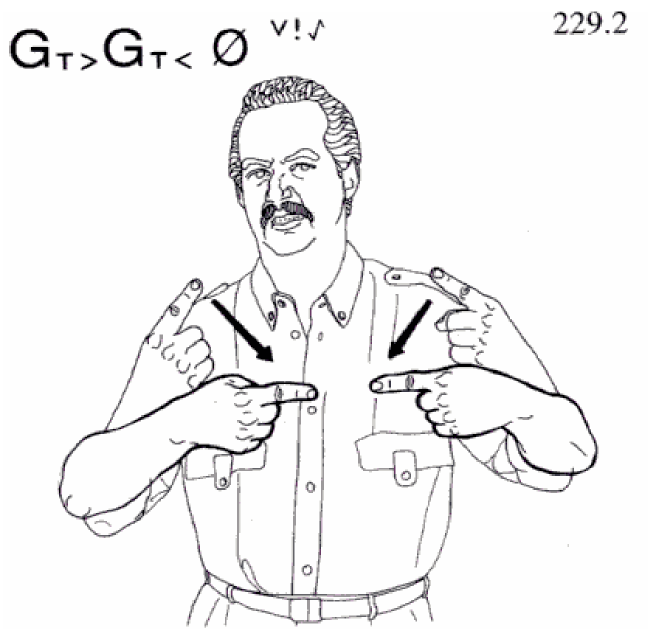

Fig. 2. Radutzky Notation for the sign: "enemies" and sign description

6 The Database

The Multilanguage Database has been designed and implemented to support the Engine Command Generation phase (Figure 1).

Figure 3 shows the database maintenance environment focusing on the relationship between the database and the overall system.

For each element of the *ISL sentence grammar* the database stores several information items, including:

1. The corresponding Italian words
2. The representation according the RNFI notation
3. The corresponding XML commands to be provided to the Graphic Engine

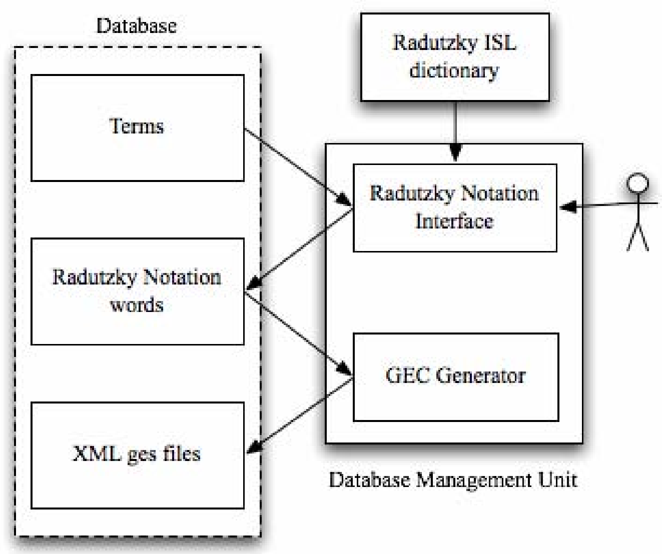

Fig. 3. Database Maintenance Environment

It worth pointing out that in Italy, ISL suffers a heavy regional influence; as a consequence, since sign languages varies form region to region, the database must store all the different "regional" notations for the a same word and provide references to the synonymous words used in other regions.

Particular effort has been devoted to the generation of the RNFI notation for each ISL element. After exploiting several generation approaches, including Optical Character Recognition of the written dictionary and using a speech to text recognizer to automatically generate the corresponding coding of each RNFI symbol read by a speaker, a manual insertion has been adopted. A custom Graphic User Interface has been developed in Java to support manual insertion of the sequence of RNFI symbol by clicking on a custom keyboard. The adopted solution proved, from the one hand, to be the fastest one, even if a training of the person charged of typing was needed, and, from the other hand, it assures extensibility towards new words and future evolution of the Italian Sign Language.

7 Graphic Engine Commands

As mentioned in Section 3, the adopted graphic engine is a commercial tool for sign language translation and synthesis used to translate American text to American Sign Language. Words are translated in commands for the avatar that displays the signs on the screen. The avatar is a VRML character that accepts XML commands; these are written in files that contain all the parameters of the gesture.

Configuration and *Orientation* are properly coded and the position (*place*) is given as a set of coordinates in the space. The *Movement* is expressed by setting configuration, orientation, and position in the space for each frame, expressed by a single XML tag.

When a sentence is given in input to the GEC Generator, it retrieves the corresponding XML commands from the database and sends them to the graphic engine for synthesis.

8 Conclusion

The paper presented the architecture and the organization of a system to support the translation from Italian to Italian Sign Language (ISL) of the deaf and its visualization through a virtual character.

The system is a joint research project between Politecnico di Torino and the Research Center of the RAI - Radiotelevisione Italiana, (Italian Radio and Television Networks).

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Web Based Personal Nutrition Management Tool

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Abstract. Internet is being used increasingly as a resource for accessing health-related information because of its several advantages. Therefore, Internet tailoring becomes quite preferable in health education and personal health management recently. Today, there are many web based health programs designed for individuals. Among these studies nutrition and weight management is popular because, obesity has become a heavy burden for populations worldwide. In this study, we designed a web based personal nutrition education and management tool, The Nutrition Web Portal, in order to enhance patients' nutrition knowledge, and provide behavioral change against obesity. The present paper reports analysis, design and development processes of The Nutrition Web Portal.

Keywords: Nutrition, web portal, web based education, nutrition education, and personal nutrition management.

1 Introduction

People access health-related information by books and other reading materials, watching television or video, using computer-based learning interventions, etc. [1] In addition to these tools, usage of the World Wide Web to access health-related information is increasing rapidly. It is reported that fifty-two million (55%) of American adults with Internet access, 38% of Turkish internet users had used Internet to get health information [2, 3]. Internet technologies have many advantages to access health information easily. For example, one can get health information to his or her learning needs whenever and wherever they need, anonymously, without having to talk with anyone and freely by web technologies [4, 5]. Therefore, Internet tailoring becomes quite popular in health education and personal health management recently.

According to Online Health Search 2006 performed by Fox et al, 80% of American internet users, or some 113 million adults, have searched for information on at least one of seventeen health topics. Among all topics; "Specific disease or medical problem", "Certain medical treatment or procedure" and "Diet, nutrition, vitamins, or nutritional supplements" are the ones which were most searched over the web [6].

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Therefore, there are many web based education and personal health management tools focused on these areas.

Nutrition and weight management is a popular issue among web based health education and management studies. Likewise, this study focused on nutrition education and personal nutrition management because, obesity has become a heavy burden for populations worldwide. The World Health Organization estimates that around one billion people throughout the world are overweight and that over 300 million of these are obese and if current trends continue, the number of overweight persons will increase to 1.5 billion by 2015 [7]. The overall prevalence rate of overweight was 25.0% and of obesity was 19.4% in Turkey [8]. Moreover, excessive weight is associated with a high incidence of cardiovascular diseases, type-2 diabetes mellitus, hypertension, dyslipidemia, osteoarthritis, and some cancers [7]. To avoid harmful effects of obesity and overweight on health, many nutrition education programs were designed by health professionals or public services.

Nutrition education is an important factor against obesity. Because, it is important to make people aware of their nutritional status, intake levels, weights as first step to maintaining their healthy behaviors or done necessary behavioral changes. To develop beneficial dietary habits, people should be informed with accurate knowledge about their own nutrient intakes [9] and this can be achieved easily by using internet technologies. In addition, web based programs provide participants personalized information that is relevant to specific needs of individuals.

Therefore, in order to enhanced patients' nutrition knowledge, we planned to design a web based personal nutrition education and management tool named as The Nutrition Web Portal. The present study reports analysis, design and development processes of The Nutrition Web Portal. Evaluation section is excluded because it is still uncompleted.

2 Method

The goal of this study is to develop a web-based tool, The Nutrition Web Portal, which provides nutrition education modules and opportunity to save and follow personal nutrition records for individuals to help their nutrition management. The portal was prepared in three phases as planning, development and evaluation. In present study, the evaluation phase is excluded because it has not been completed.

Phase 1 involved interview with dieticians, analysis of Turkish nutrition and diet web sites, literature review, determination and organization of contents and design of the portal. Phase 2, development of the portal, involves creating a database, designing and programming of the web site. During this phase SQL Server 2005, C#, ASP.NET, ADO.NET was used.

3 The Nutrition Web Portal

The portal consists of two major sections; nutrition education and personal nutrition management tool. Its personalization was provided by membership. One, who wants to use the portal must registries by filling the user registration form and determines not only his or her user name and password but also his/her nutrition habits and physical characteristics.

The goal of the Nutrition education is to provide basic nutritional knowledge to adults. Target population for educational modules of the Nutrition Portal is adults who have basic internet skills. The objectives of the educational program defined by nutrition expert are:

- Individuals understand basic concepts about nutrition,
- Define overweight and obesity and their bad effects on human life,
- Learns the ways to prevent from obesity,
- Be able to record, monitor and conclude nutrition measurements of themselves such as BMI, calorie intake,
- Learn how to plan healthy menus,
- Learn to ways to control their weight.

Nutrition education program was designed as modules on several topics. In each module, in order to motivate user and interact with the content, several learning activities, quizzes, games etc. planned. On the web site, there is also a feedback section which users can write their opinions about the education. These feedback forms will be used when evaluating the web site. The Algorithm of Nutrition Web Portal is shown in Figure 1.

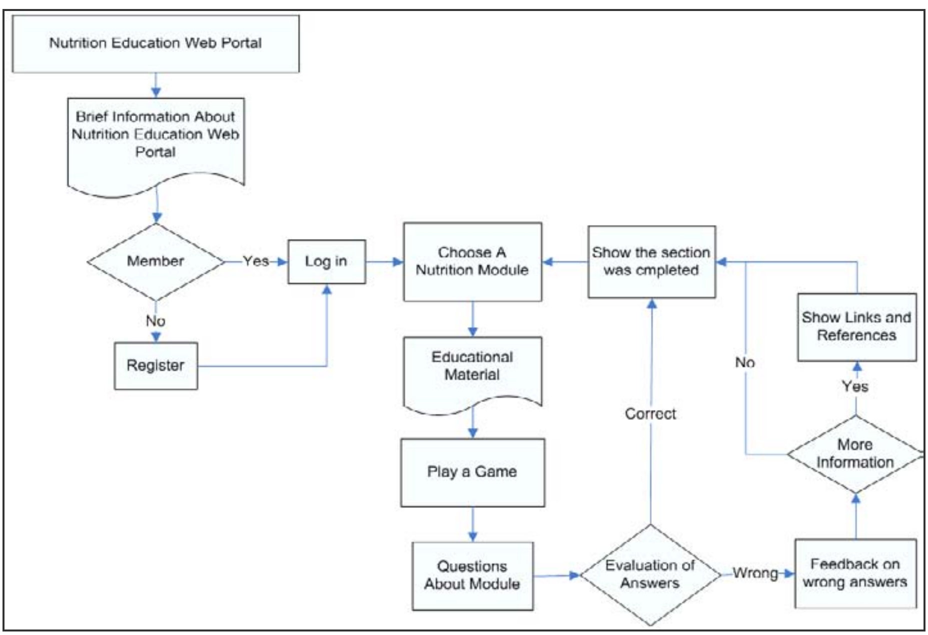

Fig. 1. The Algorithm of Nutrition Web Portal

Fig. 2. Personal daily nutrition intake record page

The portal does not only present nutrition information but also provides personal nutrition management tools. Such as calculating, recording and monitoring services for nutrition data. As recording personal nutrition data, individuals can follow the variations on their record via lists and graphs (Figure 2, Figure 3). By using two calorie calculators, which include calorie data of international and national foods, people can record and monitor their calorie intake. In addition, portal provides daily personal feedback about nutrition intakes of users. These features may help individuals to manage their weight and change nutrition habits.

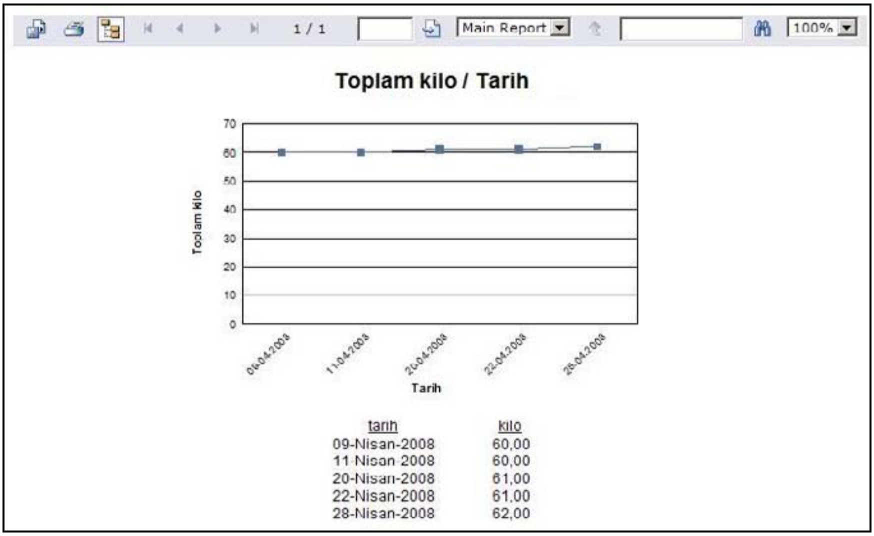

Fig. 3. The feedback page which shows personal weight changes via time

4 Conclusions

Obesity is one of the important health problems in all over the word. Considering its advantages and growing usage rates, Internet may help to increase awareness about personal health management. By providing saving and monitoring opportunities of their personal health record, it may also help people to form necessary nutritional habits and behavioral changes to avoid obesity.

In this study, we presented a web based nutrition education and management tool developed by using Internet technologies, mentioned its design and development processes. The Nutrition Education Portal may be an alternative way to achieve nutrition knowledge and manage personal nutrition behaviors. In order to observe its short term and long term effects, evaluation studies need to be conducted.

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Event-Based Data Dissemination Control in Healthcare

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Abstract. There is a movement in healthcare towards preventative care. This shift involves using technology to assist in care provision outside traditional care institutions - for instance, in a patient's home. To support such an environment, care providers require notification of incidents as they occur. However, health information is sensitive, thus the circumstances for disclosure must be controlled.

This paper provides an overview of our work on event-based data dissemination control in healthcare. We describe the nature of data-driven healthcare, and how care providers meet their data management responsibilities through fine-grained, context-aware policy rules that control the information they release.

1 Introduction

Current healthcare is organised around *acute* (reactive) care, catering for the urgent requirements of patients [1]. However, *chronic* conditions, requiring management over a period of time, consume a large proportion of healthcare resources [2]. With the ageing population, there is a global push to better manage such conditions. The way forward is through innovation, improving the use of information and focusing on preventative care [3].

Care services are becoming increasingly pervasive, where monitoring technologies are fast becoming integral to the care process. Sensors measure physiological state, allowing care outside of traditional care institutions (i.e. at the patient's home rather than in hospital). Such technologies assist in the early identification of health issues, and provide alerts in situations requiring response (e.g. emergencies). This brings benefits to patients, through improved care and quality of life, while reducing the burden on health services.

Healthcare is highly collaborative, where health providers require information in order to deliver care services. The environment is data-driven, in the sense that care providers require notification when particular incidents occur. However, health information is sensitive, and remains so over time. Thus, it must be protected. To balance these concerns, it is necessary to consider the context in which information is shared. That is, what information is appropriate to be shared in the particular circumstances.

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This paper presents an overview of how an event-based (publish/subscribe) middleware can be extended for use in a health environment. We begin by detailing event-driven healthcare, focusing particularly on homecare environments. We then discuss the sensitivity of health data, followed by a description of how context-aware policy rules can be built into the infrastructure to control the circumstances for information disclosure. We conclude by describing how to effect communication across administrative boundaries, in line with the general NHS goals of local control, flexibility and responsibility for care providers.

2 Event-Driven Healthcare

Healthcare is a highly collaborative environment, where information sharing is crucial to the provision of care. It is common that a GP refers a patient to a specialist, or to a hospital; that prescriptions are sent to a pharmacy clearing service (EPS); that certain information flows to accountants for the purposes of billing. These interactions occur across administrative domains, where each may provide a different service as part of the care process.

Homecare[1] involves providing care services for patients outside of traditional care institutions (e.g. a hospital). Sensor technologies provide detailed representations of patient state: alerting of particular incidents (i.e. emergencies) [4] and reducing the need for human intervention. Detailed physiological information assists in the early detection of issues, which may improve treatment, reducing the need for institutional care services [3]. Preventative care improves resource allocation, reducing the burden on health services [5]. The patient enjoys greater independence, requiring less institutional time (e.g. hospitals, surgeries for 'checkups') [5], while receiving more information to assist in self-care (patient empowerment) - a goal of the NHS [3].

2.1 Incidents in Homecare

Homecare environments are small and dynamic, created on demand to cater for specific aspects of a patient's well-being [6]. As such, each homecare instance is customised to the particular situation, in terms of management policy and the service providers (entities) involved. Homecare is highly data-driven: *entities* deliver services as part of the care process, requiring notification of *incidents* as they occur. Incidents include actions performed, such as a nurse administering a treatment or a patient taking a drug; observations, such as sensor monitoring reports; and state changes, such as the detection of an emergency situation.

Existing outside of traditional institutions (e.g. a hospital), homecare domains are particularly amenable to utilising care services from multiple providers. Entities require access to *relevant* information to perform their duties; depending on factors such as their role in the care process, credentials, managing organisation, in addition to patient particulars (conditions, demographics) and the current environmental state (e.g. well-being). That is, the information required by an entity to provide a service is dependent upon circumstance.

[1] The term *homecare* is used as it is expected that the home will be the primary environment for patient management. However, care might encompass mobile technologies that monitor or provide feedback while the patient is outside their home.

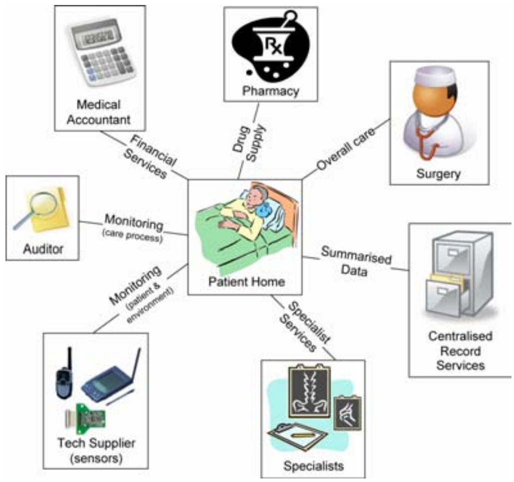

Fig. 1. Home healthcare involves interactions between entities, managed in different administrative domains, each delivering specific services as part of the care process

Infrastructure must support the active dissemination of information (incidents) while providing the means to control information disclosure, in an environment of federated administrative policy.

3 Healthcare Information Protection

Healthcare information, somewhat paradoxically, must be shared, yet protected. Notions of patient confidentiality underpin the carer-patient relationship, an ideal imposed by law [7]. Consent is the basis for sharing information, which may be implied (usually when directly concerning treatment) [8]. Carers are responsible for upholding the confidentiality of information obtained as part of the care process, and will be held accountable if information is mismanaged.

Medical professionals take this responsibility seriously. Many have expressed concerns over the risk posed to patient confidentiality by centralised record systems [9]. A goal of the NHS is to give local providers a greater degree of freedom to manage their services [10]. Local providers want control over the information they manage, as reflected in a recent BMA survey where 81% of respondents were against storing their local surgery data in centralised databases [11].

Care providers must share information to afford proper care. However, providers are responsible for protecting personal medical information. To balance these concerns, information must be shared as *appropriate* to the situation, taking into account: consent, the service the entity provides and their relation to the patient, the expected information requirements (level of detail) and the current environmental state (e.g. emergency). The mechanisms outlined here allow notions of local control to extend to information sharing, by providing the means for policy to define the circumstances in which information is communicated.

4 Event-Based Middleware

Event-based architectures suit data-driven scenarios, e.g. homecare, where principals require notification of the incidents (events) which occur within a system.

4.1 Middleware

Middleware provides a level of indirection between applications and a network infrastructure, through which all communication must pass. An *event* is a data-rich encapsulation of an incident that represents a particular semantic. Event-based middleware notifies those interested in receiving particular information as the event occurs within the system. Middleware is an appropriate point to enforce data control policy as it ensures automatic compliance by applications.

4.2 Publish/Subscribe

Publish/subscribe [12] is an asynchronous messaging paradigm suited to event-driven environments. A principal takes the role of a publisher and/or a subscriber. Subscribers register their interest in receiving particular information through a subscription. Publishers produce events (information) independent of subscribers. Principals communicate through event brokers, which route events from publishers to subscribers. Through a process called notification, events are delivered to subscribers with matching subscriptions. Essentially, a subscriber requests particular information, which is delivered by the middleware upon the publication of an event matching that request.

A key feature of the paradigm is that information producers and consumers are decoupled. This saves burdening producers with the addressing specifics of every information sink. Instead, consumers declare their interest in receiving particular information, leaving the middleware to deliver relevant publications.

We have coupled a publish/subscribe middleware into a database management system, to allow a database to act as a messaging broker [13]. This allows a broker to produce and consume events, facilitates data replication through a common type interface and allows rich representations of state (e.g. through stored data and functions). This database-broker integration provides an appropriate point for enforcing data management polices.

4.3 Interaction Control

Interaction control refers to the customisation of data to circumstance [14]. It involves loading policy rules into a broker to define the situations for data release. Three types of policy rules function to control data[2]:

Subscription authorisation. These define the circumstances in which a user may subscribe (request) particular information for delivery as it occurs. An example rule might allow a Doctor to subscribe to Treatment events, but only for patients that he treats.

[2] A detailed description is provided in [15]. See Section 6 for examples.

Event restriction. These rules define the conditions in which certain events are restricted (not delivered) for an active subscription. For example, a rule might prevent a particular doctor from receiving events concerning a patient's HIV treatment. Restrictions are imposed silently, to not reveal to the subscriber any sensitive information encoded in the restriction itself. Restriction differs from subscription authorisation, in that it stops propagation of particular information, even if the subscription channel (general request) is authorised and established.

Event transformation. Transformations involve altering an event instance, changing attributes, values or the event type to better satisfy the information requirements of the subscriber, current context, etc. That is, the content of the information can be customised to suit the particular circumstances.

Policy rules are enforced in a broker to bring about information control. Rules are context-aware, referencing various aspects of state, including 1) messaging substrate information (principals connected, event content), 2) user credentials (e.g. roles held) and/or 3) environmental state (referencing local data or external services). It is these context-sensitive policy rules that allow fine-grained control over information dissemination, allowing policy to account for both general cases and exceptions (such as emergency overrides).

As the environment is event-driven, events themselves serve to alter environmental state. This means that the control mechanisms are responsive to changes in context. For example, if an event occurs meaning a doctor no longer has a relationship with a patient, then their subscription is deactivated (if appropriate).

Typical access control mechanisms are binary in nature: permit or deny. Transformation provides more, allowing aspects of an event to be changed; perturbing or enriching values or encapsulating a different semantic by converting an event into another type. This is a powerful mechanism that, in addition to allowing fine-grained control over information release, may also help with interoperability - mapping between the data models of applications and domains, and in providing summary data for surveys, such as epidemiological reports.

5 Cross-Domain Communication

Each administrative domain (e.g. doctors' surgery, specialist laboratory, hospital) maintains a broker[3] to serve as its point of communication. Entities producing information within a domain will publish events to their local broker. Events, subject to access policies, are delivered to the subscribers to this information, where a subscriber may be grounded in the local or an external domain.

Information flow is controlled through the definition of policy rules at its local broker, allowing each administrative domain fine-grained control over the circumstances for data release. This allows them to meet their responsibility for protecting patient information, sharing only in appropriate circumstances.

Entities seeking information receive it from the administrative domain responsible for that data. For example, a doctor seeking information on some test results will have their subscription satisfied by data from the relevant pathology domain. Both local

[3] Multiple brokers may facilitate communication; for simplicity we refer to one.

(domain-specific) and global (NHS-wide) services, such as the Electronic Staff Register, Legitimate Relationships and Patient Workgroups, can be used to identify information sources, in addition to providing information on which to base disclosure policies.

6 Health Scenarios

This section describes the application of our data control framework to two healthcare scenarios[4].

Drug auditing. This example, see Figure 2 A), shows how the Surgery domain controls the visibility of prescription information released to external parties. Homecare nurses may prescribe drugs, including controlled drugs (e.g. morphine) in certain circumstances [16]. Prescriptions must flow to the Electronic Prescription Service (EPS), without details of patient observations and the reason for the prescription (i.e. care record specifics). The supply of controlled drugs must be monitored by an auditor [17]. As the audit is prescriber focused, the auditor should not receive patient specifics unless the prescriber is under investigation[5].

Location privacy. Typical homecare scenarios use sensors to measure aspects of physiological state, transmitting this information to a remote store. Location sensors are common in such environments, and may detect the room of the house the patient

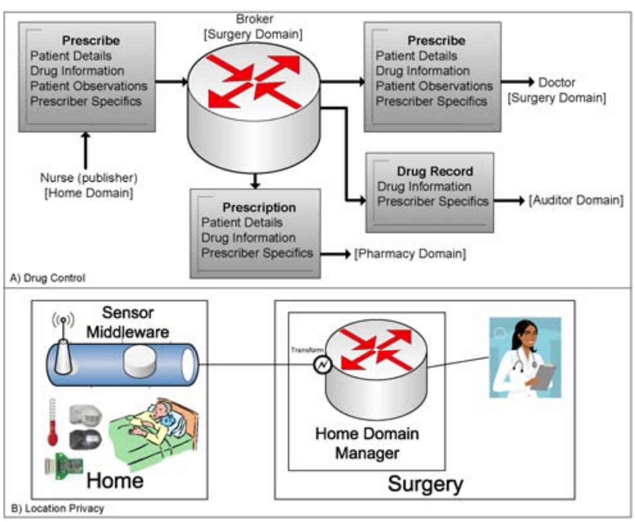

Fig. 2. A representation of the dataflows for the scenarios

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[4] We model the Surgery as the information management domain, as it houses the doctor (case-manager) directly responsible for the care of the patient. In addition, it provides a more stable infrastructure than a home environment.

[5] To deal with this, the transformation rule creating the Drug_Record event is conditional on whether the prescriber is being investigated.

is in, or their GPS location. Precise location is important in emergencies, e.g. to inform A&E of where to dispatch the ambulance, and to help in the interpretation of sensor information (are they in bed? collapsed on the kitchen floor?). In the general case, a patient may prefer that their precise location is obscured. To interpret data, it may be sufficient to know whether the patient is in their familiar home environment, or elsewhere and thus subject to external stimuli. A single transformation rule can encapsulate these requirements, degrading the quality of location information except in emergency situations.

These examples highlight key features of the middleware. Firstly, that each domain manages its information: the Surgery domain meets its data handling responsibilities by only releasing that information required in the particular situation. It shows that one incident has relevance to many parties, where data visibility is managed within the infrastructure (cf. through applications). Further, we show how environmental state (context) can be used to alter the granularity of the information provided - as opposed to denying event transmission, hindering care, or transferring the complete event which raises privacy concerns.

7 Discussion and Conclusion

We have outlined a framework for controlling event-based information flow according to context. We feel that such an infrastructure provides a suitable base for managing information in data-driven healthcare environments.

Event-based paradigms, while effective for data dissemination, generally lack the rigorous access control mechanisms required by health infrastructure. By incorporating data control rules into the middleware layer, we force policy adherence. The integration of messaging and database systems allows for rich representations of context, while increasing performance by removing any communication overhead between the two substrates [13]. Further, health systems depend on theuse of database systems. By imposing a layer above technology commonplace, in NHS infrastructure, implementation and integration overheads are reduced.

Some recent debate concerns the use of centralised data stores. Our focus is on supporting the heterogeneous nature of the health service - where information flows across administrative domains. The NHS aims to give a greater degree of freedom and control to service providers. Our approach allows this notion to extend to the management of health information, giving those responsible for data fine-grained control over the circumstances for its release. Federated environments are scalable, and improve accountability by providing visibility of those responsible for information misuse or mismanagement (inadequate protection). The risks associated with centralised data stores are higher, as more users have the potential to access more information [18]. Care providers hold and require information relevant to their service, thus it is natural that they manage and are responsible for this information, respecting the privacy requests (consent) of their patients. Note that although this work is presented in the context of supporting environments of multiple, autonomous administrative domains, equally it can control data in more centralised architectures.

Future healthcare environments will be highly data-driven, involving interactions between patients, professionals, agents, sensors, etc. Infrastructure is required to allow information to be shared, but also protected. We have presented methods to balance these concerns, by allowing information holders fine-grained control over the circumstances in which information is disclosed. This approach, built on common technology (database systems), supports the general NHS goal of local control and responsibility. Information protection is improved - responsibility means accountability. Federated data management not only mitigates against risks to confidentiality, but provides a realistic solution to managing the heterogeneous nature of the health service.

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Decision Support Systems: Improving Levels of Care and Lowering Costs in Anticoagulation Therapy

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Abstract. The objectives of this work in progress are to improve the levels of care in anticoagulation therapy while reducing the effort required and the costs. This will be achieved by the preprocessing of the available real world data and projecting it into a suitable analysis space before modelling with individualised, constantly learning Evolving Takagi Sugeno [1] and Connectivist Network-type models whose structure and parameters are the result of extensive research. It is hoped that this will lead to accurate predictions of the future levels of anticoagulation from a given dose recommendation.

Keywords: Decision Support Systems, Classification, Prediction, Anticoagulation.

1 Introduction

The increasing age of the population is a significant factor in the increasing demand for anticoagulation therapy [2]. The preferred treatment is an orally administered Vitamin K antagonist, typically Warfarin. Such treatment is both risky and expensive. Under-anticoagulation increases the risk of a thromboembolic event and over-anticoagulation increases the risk of haemorrhage. The coagulability of the blood is measured in International Normalised Ratio (INR) units. The medical goal is to keep this value within an indication-specific therapeutic range. Clinicians are only able to achieve this for 50% of the duration of treatment [3]. There is clearly room for improvement in the level of care. Regular clinic visits are costly and do not lead to a good patient experience.

Decision support systems have been widely used in anticoagulation clinics since it was shown that they perform at least as well as the clinicians [4]. Often the software includes workflow functionality specific to anticoagulation clinics and uses a proprietary algorithm to recommend a dose and test interval. Even with such software clinics rarely achieve better than 70% of a patient’s time in the therapeutic range [5]. The challenge here is to increase the time patients spend inside their therapeutic INR range. This will reduce the number of clinic visits with the associated benefits of reducing costs and improving the patient experience and quality of treatment. This retrospective study uses anonymous anticoagulation data collected in the DAWN AC Decision Support Software for a benchmarking service which aims to improve care at participating clinics. Data is available from five unknown clinics for five six month

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periods from April 2003 to October 2005. Data is available for 19585 patients and represents around 50000 patient treatment years. This huge volume of real world anticoagulation data offers an excellent opportunity to study patients' INR time series in detail and should ensure that the results can be generalised to the wider community of patients.

2 Methods and Challenges

The goal is to enhance the results achieved by the DAWN AC System using new INR time series modelling techniques that complement the existing algorithm. This will allow for the accurate prediction of a patient's future level of anticoagulation based on a current Warfarin dose and next visit interval recommendation. Thus the aim here is to help the clinician to arrive at a better dosing decision with less effort and therefore obtain more stable INR levels and longer test intervals. It is known that patients react quite differently to the same dose of Warfarin and that their responses change over time. Hence two key ideas are proposed:

- modelling of INR responses on a per individual basis, over and above common behaviours
- update of patients' models at every clinic visit to learn previously unseen responses

These two simple ideas should bring an improvement in modelling. Other key enablers are:

- sensible pre-processing of the extensive real world anticoagulation data, in order to remove unrealistic outlying values
- novel representations of the data in the input space
- the use of powerful modelling techniques, namely Evolving Takagi Sugeno (eTS), eClass [6] and network-type models respectively
- new visualisation methods will help the clinician identify unusual and/or dangerous patterns in the INR time series

The key challenge in assessing the impact of any given Warfarin dose recommendation is the number of other factors that affect the coagulability of the blood. Many of these factors are not measured or reported to the clinician during the visit. Typical factors are dose compliance, drug interactions (Aspirin, Paracetamol, Amiodarone, Antibiotics, and more), lifestyle (smoking, drinking, and exercise), diet, general health, and the time elapsed between the latest dose and the clinic visit measurement of the INR. Furthermore, there is noise in the measurement and recording of INR values. Due to the above reasons, it is immediately apparent why excellent levels of care (treatment quality) are very difficult to achieve.

3 Experimental Results

Currently two types of INR modelling techniques have been developed and tested using real data: a real-valued point prediction of the next INR measurement [7] and a classification prediction if the next INR reading will be in or out of the therapeutic range. The simpler INR classification method has proved to be very effective. A single real value between zero and one is produced by the network model while the eClass model (a classifier built on eTS technology) produces two real numbers which are normalised before the optimum decision boundary is selected based on the classic Receiver Operating Characteristic Accuracy measurement. This is calculated by dividing the total number of TRUE predictions by the total number of predictions. Furthermore, the True Positive Rate (TPR) and True Negative Rate (TNR) give an indication of how well each class is predicted. After preprocessing the entire data set 14181 patients remained of which 1000 were used to train the models before testing the proposed schemes with the remaining 13181 patients (comprising 404023 clinic visits). The peak accuracy results are presented in the table in figure 1 below. It is interesting to note that eClass performs well even though it is not being used optimally. eClass and eTS are designed for online operation starting with no pre-training, whereas here the eClass model is pretrained for equivalence with the network. The models' average time taken to estimate the next INR measurement and then adapt to the measured value can also be found in the in figure 1. eClass operates much more quickly than the network-type model. Further to this, eClass and eTS maintain a rule base of the form:

if (INR is *x*) and (dose is *y*) and (interval is *z*) then (next INR is *a*)

This can provide some understanding of the INR response to dosing instructions for the clinicians. Networks are 'black box' models where the internal weights and bias values are not interpretable at the application level.

Table 1. Table of Classification Accuracy of the Dawn AC, eClass (eTS), and Network-type Models

System	Max Acc (%)	TPR (%)	TNR (%)	Average Time per prediction and train (seconds)
Dawn AC	56.8	56.8	0	N/A
eClass	74.4	65	52.7	0.0046
Network	89.1	83	88.6	0.328

Real values of the next INR reading are more difficult to predict. Using the fuzzy rule-based eTS method with preprocessed data and transformation of the input data a mean squared INR prediction error (MSE) of 0.375 has been achieved for 1000 train patients and 1000 test patients. Using exactly the same data, a network-type system produces an average INR prediction MSE of 0.987. Both types of model adapt with a patient's changing responses but eTS has the advantage of achieving this by changing its internal structure whereas networks change their internal weights but not their structure.

4 Conclusions and Future Work

These results show that a more sophisticated modelling of patients' INR responses is possible if the input data is carefully preprocessed and projected into a suitable input space. These transformations separate the influence of the different factors (as discussed above) from the actual Dose/INR response mechanism allowing both to be modelled separately. The two category classification of whether the following INR measurement will be in or out of range is very accurate. The connectivist network-type models outperform eClass in terms of classification accuracy but they do not provide any understanding of the problem and work two orders of magnitude slower. A three way classifier will be developed. A final step will involve suggesting optimum dosing recommendations (both Warfarin dose and visit interval). Work is under way to improve the existing real-valued INR prediction results.

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NHS Blood Tracking Pilot: City University Evaluation Project

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Abstract. Automation of healthcare processes is an emergent theme in the drive to increase patient safety. The Mayday Hospital has been chosen as the pilot site for the implementation of the Electronic Clinical Transfusion Management System to track blood from the point of ordering to the final transfusion. The Centre for Health Informatics at City University is carrying out an independent evaluation of the system implementation using a variety of methodologies to both formatively inform the implementation process and summatively provide an account of the lessons learned for future implementations.

Keywords: Blood transfusion, RFID, Evaluation.

Every day, thousands of routine and emergency transfusions take place across the UK, the vast majority being carried out safely and without adverse incident. However, due to the complex sequence of activities, occasionally mistakes do occur. Transfusion of the incorrect blood type - known as 'ABO incompatibility' - is the most serious outcome of blood type error, primarily resulting from the failure of final identity checks carried out.

Research by Serious Hazards of Transfusion (SHOT) has shown that between 1996 and 2004, five patients died directly resulting from being given incompatible blood. Furthermore, ABO incompatibility was a contributing factor in the deaths of nine patients and caused major illness in 54 patients.

Stringent standards and regulations have been created by national healthcare bodies with the ultimate aim to enhance patient safety. In 2005 the Medicines and Healthcare products Regulatory Agency (MHRA) produced the Blood Safety and Quality Regulations to maintain a complete traceability record for all blood components and products from donor to recipient for 30 years. In 2006, the National Blood Transfusion Committee (NBTC) along with the National Patient Safety Association (NPSA) and SHOT issued the 'Right Patient, Right Blood' Safer Practice Notice which provides recommendations for improving the safety of blood transfusions, including an IT specification, the Electronic Clinical Transfusion Management System (ECTMS) guide.

Stemming from this knowledge and the continuous drive by healthcare organisations to improve patient safety, the NHS Connecting for Health (CfH) group and the NPSA have been in collaboration with the Mayday Hospital Trust to carry out a pilot of a new electronic blood tracking system according to ECTMS guidance. The

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guidance provides a ‘gold standard’ for the automation of the blood transfusion process from identifying a patient and ordering of blood transfusion, through to the taking of blood sample for cross-matching, to final transfusion of the blood product. The expected benefits to be gained by the deployment of an electronic blood tracking system range from reducing inpatient safety incidents, reducing the number of samples rejected by the lab, automated information checking, enhanced accountability and audit trail, and improved traceability of blood/blood products.

The Mayday Trust will be using pilot areas of the hospital to assess how the use of the Trust’s wireless local area network, Order Communications System, Pathology Laboratory Information Management System, Radio Frequency Identification (RFID), wireless fidelity (WiFi) and barcodes (linear and 2D) can be used to support adherence to the ECTMS guidance and reduce human error.

The team at the City University Centre for Health Informatics has been commissioned by NHS CfH to undertake a full independent evaluation of the Mayday NHS Trust pilot to ensure that the process is recorded, user views are accounted for, and recommendations about the implementation and effectiveness are useful to share with other NHS Trusts looking to use the IT specification. The evaluation will be collaborative with the Mayday and CfH, will incorporate formative, summative and comparative elements.

The project will use a mixed conceptual framework to guide the evaluation. The Project Research Objective Evaluation (PROBE) framework [1] (produced for the NHS Information Authority) is being used to generate the relevant research questions/ objectives according to five evaluation areas – strategic, financial, human, operational and technical. This framework is merged with a classic model to assess Information Systems (IS) success, the DeLone and McLean (updated in 2003) framework [2], which is being used to generate lower-level criteria to answer the specific higher-level research questions. This looks at six interrelated dimensions of success: system, service and information quality, use/intention to use and user satisfaction, and finally net benefits (hierarchically from individual to overall system). Concurrent assessment of the adherence to CfH, NPSA and MHRA standards and guidance will also be carried out.

A multi-method approach will be used throughout the evaluation process to ensure assessment of the many dimensions of the implementation project and that an optimal amount of detail is captured from numerous angles. Both qualitative and quantitative methodologies will be used longitudinally to continually assess progress and feed back to stakeholders and the implementation team as part of the formative component of the project. Social research methods will be used to assess the human factors throughout the implementation, an arguably crucial element often omitted from IS evaluations. A triangulation approach is being used to study user, stakeholder and patient views using the semi-structured interviews, surveys and document analysis. Both statistical and qualitative analysis techniques will be used with the data gathered.

Quantitative methods will be used to track the effects of the blood tracking system, mainly via the Mayday’s own pathology database system as a source of data. The evaluation team is also recording other factors such as issuing of second wristbands, training trajectories, process timings and observational auditing of standard operating procedures in the transfusion process according to a proforma created by the Oxford Radcliffe Hospital Trust as a basis for external comparison of conformance with the

ECTMS. The rate of uptake of the new system is key to the concept of transferability between trusts and will be primarily assessed by examining changes in usage in the old versus new system over time. Numbers, rates and reasons for blood request, blood usage and blood samples rejected by the lab will also be tracked, as will adverse incidents reported by the Mayday transfusion team.

With further evaluation of the nature and effectiveness of the automated blood tracking system, further applications to other aspects of healthcare administration such as drug tracking may be explored.

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eHealth and Global Health: Investments Opportunities and Challenges for Industry in Developing Countries

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Abstract. eHealth investments from developed countries to developing countries are expected to follow the emerging trend of eHealth for meeting global health problems. However, eHealth industry from developed countries will need to learn to make this impending venture a 'win-win' situation with profitable return on investments. This short paper highlights some of these challenges that must be overcome in order to achieve these objectives.

Keywords: eHealth, developing countries, investments, industry, challenges, global health.

1 Introduction

This paper aims to open the discussion on how global private eHealth private sector or industry should transfer their technologies to developing countries (DCs). It forms a part of a work in progress on understanding the factors mediating the sustainable adoption and diffusion of eHealth services in DCs especially those in Africa [1]. Tackling global health challenges is a strategic agenda for most developed countries and encouraging their private sector to engage with public health services seems to be an emerging business model. eHealth, the use of information and communication technologies (ICTs) for supporting healthcare process is already forming part of this global health agenda.

Globalization has led to the adoption of ICTs for international development by these developed countries. An unexpected spillover of this policy shift is that according to Heeks (2008) [2] it presents new business opportunities for ICT industry from these countries. Further, opportunity for these countries amongst others is the economical benefits of opening up markets for their products and services [2].

eHealth for international development is not without its own history. Going down the memory lane, the now inactive G-8 Global Healthcare Applications Subproject-4 (G-8 GHAP-SP-4) (Circa 1995-2002) [3] set the tone for these countries to contribute to global health development through eHealth. However, notwithstanding the observed lack of activity of this initiative, other G8 countries have recently started to develop their own strategy in this regard and it seems that it has been resurrected and

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reincarnated by the American Telemedicine Association (ATA). Recently, the ATA brought together global experts under the Global Forum on Telemedicine to foster global cooperative alliances in how eHealth can contribute to global health challenges [4]. In addition, it is also likely that the UK government might employ eHealth for her global health commitments in DCs going by a recent policy document authored by Sir Nigel Crisp titled *"Global Health Partnership: The UK contribution to health in developing countries"* [5].

Regional economies such as the Commonwealth and European Union (EU) also have eHealth as a strategic tool for meeting their global health commitments. The EU IST FP7 and other technology related projects with DCs is an example in this regard. The EU-Africa Lisbon Strategy exemplifies this strategic shift of using eHealth for meeting global health challenges through private/industry sector participation [1]. This global political trend, expected here to be embraced by eHealth industry as business opportunities, should be seen as a beneficial development. Involving private sector in product and service innovations for tackling global health challenges is a practice that will yield benefits for DCs' populations [6].

However, emerging literature on eHealth economics, suggest that private eHealth industry will have to overcome six main obstacles in order to achieve sustainable and profitable investments [7]. These challenges will need to be understood and effectively managed in order to ensure their return on investments (ROIs).

2 Challenges to eHealth Investments

Understanding the: dynamics of eHealth adoption and diffusion within specific geopolitical region and health organizations; contextual and cultural background by engaging with multiple health stakeholders; dynamics and nature of health systems reforms and rapid technological changes; process of converging the different business philosophies of industry and health sectors, developing 'win-win' business models; process of technological R&D, funding and evaluation within health sector; nature of local eHealth policies, legal structures, standards and partnerships development. It is therefore a position of this paper that any eHealth technology transfer by the industry to DCs' health sector should incorporate and strategize to overcome these challenges in their investment plans.

Moreover, bearing in mind that health services delivery in most of these DCs are public-sector driven, developing workable public-private partnerships (PPPs) should be of interest eHealth business or industry from these high income countries. Research evidence suggests that north-south technology transfer and eHealth implementations are complex and contentious issues with numerous recorded sustainability failures [8], therefore, the need to understand these contextual issues are deemed important for success [9]. As the financial burden of ICT failures is not a luxury that the fragile economies of these countries can sustain, this- should also be of paramount interest to eHealth business or industry.

Already, insights from eHealth projects in DCs could provide solutions to eHealth industry on how to overcome some of these eHealth investment challenges. For instance, business partnerships should take the form of a social enterprise model. This was found to be a sustainable business model for eHealth investment in a DC [10].

Limited financial resources and erratic electrical power supply has made the mobile/wireless ICTs to be sustainable for providing eHealth services in these regions. The use of mobile computers powered by locally fabricated solar panels for eHealth purposes have been demonstrated in Uganda for the past three years [11].

Any technology to be deployed must be low-cost and local R&D and “micro-industrialization” to support this is a sustainable business model from a widely known health enterprise in a DC [12]. Also, any eHealth R&D and transfer should adopt an ethical approach to intellectual Property Rights (IPRs) management [13]. A good practice that should be adopted in this regard is from the World Health Organization joint initiative with Connecting for Health (CfH), UK. Here-CfH will share its eHealth innovations with DCs under the emerging *“Sharing eHealth Intellectual Property for Development”* (SHIPD) [14]. Engaging local firms in these R&D process could help the industry in marketing and distributing their products in a cost-effective way. Aside, collaborative global-local eHealth R&D will make it possible for local firms to develop their capacity to innovate for local health needs [6].

Acknowledging that, there are differences in economic and technological capabilities of different DCs, the argument pursued here will therefore require certain contextual factors taken into consideration. Regional variations; as in countries from Africa, South America or Asia is an important factor. Emerging economies such as South Africa, Brazil and India are countries from these regions with more advanced economic clout and technological innovations that can even rival those from developed countries. Aside; health system configuration, market size, business climate, enabling legislation, infrastructures and policies are different factors at both national and regional basis that will determine the nature and dynamics of eHealth investments.

3 Conclusion

The emerging global shift in foreign policy of developed countries to adopt eHealth for tackling global health challenges in DCs, will inadvertently stimulate their private sectors to transfer eHealth investments to these countries. On the other hand, eHealth investments from DCs, especially from those of emerging economies are expected to go move towards the opposite direction in the nearest future. Low-cost, low-power and open source technologies already established in countries like Brazil and India might provide a competitive advantage for them to compete in the global eHealth markets. Already, outsourcing of eHealth services like radiological and hematological interpretations and diagnosis to DCs from developed ones is on the rise, due to better cost-saving advantage. Finally, however, global private eHealth investors or industries should develop their business strategies to overcome the above identified obstacles and potential ones. Incorporation of these insights is strategic, in order to achieve profitable ROIs.

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Web-Based Architecture to Enable Compute-Intensive CAD Tools and Multi-user Synchronization in Teleradiology*

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Abstract. Teleradiology is the electronic transmission of radiological patient images, such as x-rays, CT, or MR across multiple locations. The goal could be interpretation, consultation, or medical records keeping. Information technology solutions have enabled electronic records and their associated benefits are evident in health care today. However, salient aspects of collaborative interfaces, and computer assisted diagnostic (CAD) tools are yet to be integrated into workflow designs. The Computer Assisted Diagnostics and Interventions (CADI) group at the University at Buffalo has developed an architecture that facilitates web-enabled use of CAD tools, along with the novel concept of synchronized collaboration. The architecture can support multiple teleradiology applications and case studies are presented here.

The architecture is associated with a GUI that enables DICOM viewing and annotation, capabilities that are standard in popular workflow solutions. The architecture integrates computer vision algorithms that normally require large computing power into the workflow process. Unique enhancements have been added to the UI in the form of collaboration tools developed specifically for teleradiology.

1 Introduction

The demand for electronic, web-enabled solutions in health care has led to several advances in UI designs and architectures for diagnostic imaging. Workflow solutions currently provide several useful features: single interface for multi-modality images, measuring tools, support for hand-held device, access to remote/local patient information, encryption [1,2,4,6]. These measures that were revolutionary a few decades ago, are now standard tools in health-care facilities. However, significant potential remains untapped in the design of collaborative interfaces, and integrating image processing routines into workflow designs.

We have implemented an architecture that enables Computer Aided Diagnostics (CAD) and synchronized teleradiology solutions (Figure 1). Popular PACS features like DICOM image loading, encryption etc. are provided along the lines

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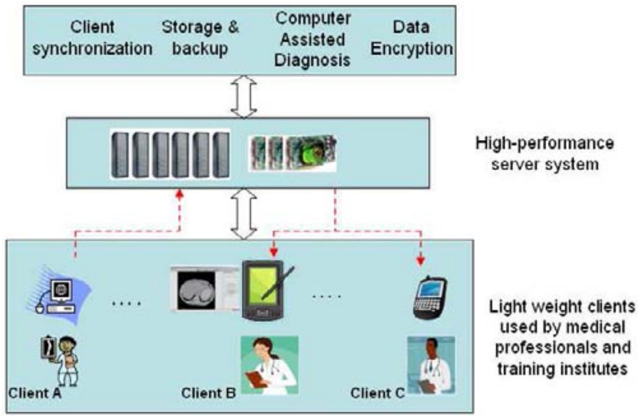


Fig. 1. Architecture of proposed teleradiology system. The normal workflow is shown in block arrows, where client systems interact with the servers independent of each other. The dotted arrows indicate synchronized workflow; interactions performed by client A is sent to clients B and C.

of industry-standard client-server architecture. The novel aspect of our design is the introduction of CAD tools in the server application, and the provision of synchronized collaboration.

2 CAD Tools

Surgery and treatment planning often involves the review of several images, sometimes of various modalities. Physicians have to frequently note salient image features manually and use the annotations to make diagnostic decisions during surgical planning or treatment. For example, in radio-therapy, the boundaries of neural structures like the optical nerve or brain stem are marked. The locations of these structures is used to guide therapy decisions. Similarly, physicians mark out boundaries of the liver and other salient organs prior to performing abdominal procedures. Several image processing algorithms are available to automate the identification of such structures [3,5,7,9]. The compute power needed for such image processing tools is significantly higher than the compute power needed to perform tasks like image viewing/browsing. For example, some automated techniques for liver segmentation require more than 120 seconds on a high-end processor like the NVIDIA 8800 GTX.

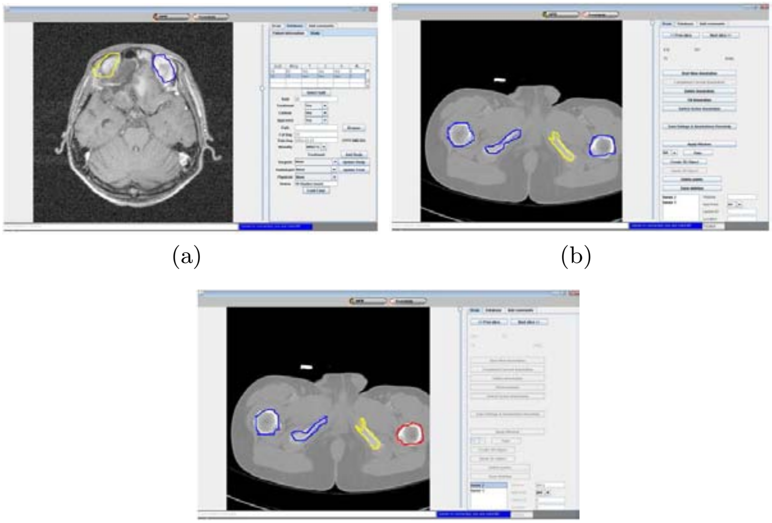
Several image analysis algorithms cannot be executed on thin clients like PDAs or laptops, but the automated features of these algorithms can significantly assist physicians in surgical and treatment planning. Our architecture separates the compute requirements from the client; the compute intensive image analysis algorithms are executed on a server system which has a high bandwidth network connection. The image analysis algorithms often use parametric models which need to be tweaked by suitable user input(s). UI controls are provided to enter the values of such parameters. For example, in case of MRF based segmentation, the user needs to provide one point within the liver. The seed point and liver image is transmitted to the server where an MRF algorithm [3] is applied to grow a region around the seed point and obtain the liver boundary.

2.1 Synchronization Tools

Radiologists often discuss difficult pathologies with colleagues, or provide information sessions to patient groups. Participants in such sessions may be from different geographic locations, and off-the-shelf teleconferencing, or desktop sharing packages are used to conduct the proceedings. We have devised a system where the ability to perform such collaboration has been integrated into the teleradiology interface.

A synchronize menu is available in the UI to initiate collaborative sessions. For a particular user (Client A in figure 1), the menu displays a list of users who are authorized to view their images. The authorization scheme is determined by workflow restrictions or HIPAA polcies, and any set of conditions can be encoded into the program by IT administrators. As Client A selects users from the menu, a request to collaborate is sent to the selected users. When a user (Client B, C in figure 1) accepts a request to collaborate, the server examines the patient information displayed by Client A, and sends the same information to clients B, C. Any interaction that is made by Client A on his UI is also transmitted to Clients B, C. For example, if Client A moves from slice 10 to slice 14, or performs window level operation, the same operations are performed in that sequence in the UIs of clients B and C.

The synchronize feature is a significant move away from using teleconferencing or desktop sharing packages. Off-the-shelf packages do not provide an accurate reproduction of the pathology information, especially the detail needed in cross-consultation for difficult cases. Software and hardware restrictions placed by teleconferencing tools destroys the ability to access patient information using small form factor devices like PDAs. Since only the UI controls are transmitted between collaborating clients, the bandwidth requirement is low and UI response is instantaneous in our case. For instance, once the patient information that is being seen by Client A has been reflected on clients B and C, the only information transmitted is about actions have been performed with UI. The server can embed UI controls into small messages like "Set window level to X/Y", or "Change to slice 14". The messages are transmitted over the network, automatically interpreted by the client software, and suitable changes made in the UI. This process requires no more bandwidth or compute power than is needed to display patient data. In addition, patient data and images do not leave the secure, encrypted, HIPAA compliant environs of the architecture. Some of the user interfaces are shown in figure 2.



(a) (b)

(c)

Fig. 2. Screen layout of the UI

3 Case Studies

The teleradiology architecture has been deployed in the Roswell Park Cancer Institute (RPCI) at Buffalo, NY. Physicians at RPCI measure the effectiveness of treatment by tracking brain lesions over a period of time. Our architecture provides an intuitive paint-like interface to draw annotations over brain MRI, enter pathology information related to the lesions, and save the information to a database. The system has been deployed with three clients connecting to a server that has regular backup. The system is integrated with several CAD routines that are discussed in [3,8].

The architecture is being deployed in the Dent Neurological Center at Amherst, NY to help facilitate radiologist and patient education programs. Periodically, radiologists at different geographic locations discuss certain difficult pathologies, or provide information sessions to patient groups about radiology problems. Currently, off-the-shelf teleconferencing packages are being used to conduct such collaborative sessions, and information meetings. The radiologists have indicated a need to have a dedicated system that can relay images and pathology data. This has found to be more critical in radiologist interactions than in patient information groups.

A data collection process and study of the UI and segmentation algorithms has been initiated in collaboration with Dr. Stanley Lau from the Women and Children's hospital of Buffalo, NY [3].

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Research Challenges in Future Health Care Systems*

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Abstract. Future health care systems will involve a network of heterogeneous resources providing different levels of service and will comprise of a physical and a virtual decision and control layer. The initial results presented here will lead to health care delivery with on-line decision making in order to meet QoS requirements and management targets.

Keywords: Dynamic resource allocation, cost optimisation, adaptive performance evaluation.

1 Introduction

Recent technological developments in health care include biomedical sensors, implanted medical devices, home monitoring, nurse-bots among others. Therefore it can be envisaged that any future system will require these and such disparate resources networked and integrated to provide health care services. Many scenarios have been developed to predict the future of health care systems. These future systems will need to model more than just the digital technologies that make up part of this scenario. Proper functioning of any health care system is related to the physical world that the digital technologies interact with and most importantly the human interaction which is the medical staff, administrators, other services personnel and patients who are a vital part of its functioning. This generates new research challenges which require a multi-disciplinary endeavour from all relevant research communities.

2 Research Challenges

A new mathematics that merges the digital and physical worlds will be needed to understand all aspects of future eHealth systems. These systems will need to acquire information through heterogeneous and geographically separated input sources. Management of such systems will have to integrate with the virtual layer, decision layer and the physical layer in order to achieve a set of global and/or local objectives. Some key challenges to be considered will be,

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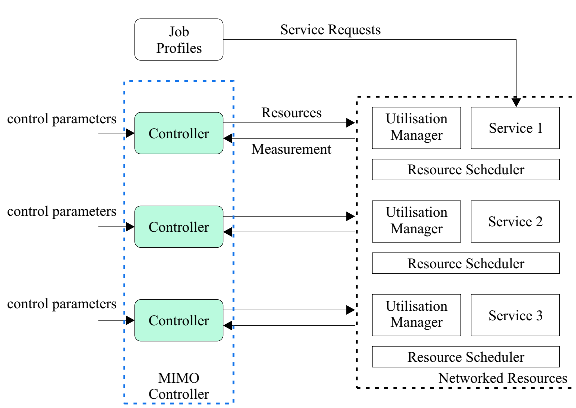
– Ability to adapt to emergent behaviour
– Ability to approximate complex systems
– Ability to merge time-based and event-based systems
– Ability to deal with systems that have both discrete and continuous components
– Ability to deal with unequal time units, where the next update time is randomly distributed
– Ability to include human interaction

The operation and control of future health care systems is therefore a complicated task and the lack of a fundamental calculus will lead to an informal and ad-hoc engineering techniques.

3 Control Theoretic Approach

Health care management systems will have high transaction volumes over varied access mediums such as the web, wireless, face-to-face contact etc., and will involve service delivery using a network of heterogeneous and limited resources. The operation and control of this system needs to be at optimum performance as determined by the service level agreements and health care policies.The ability to predict and allocate limited resources in order to meet QoS requirements at each time instant based on the feedback received of the current utilization will be a considerable advantage. The described scenario will lead to health service delivery that involves strategic decision making and provides on-line, on-demand cost evaluations based on actual and predicted service demands.

The goal will be to use a control theoretic approach to explore new performance driven architectures for automation of health care management and resource allocation tasks. This will simplify the human administrative task by



(a) Schematic of feedback control system

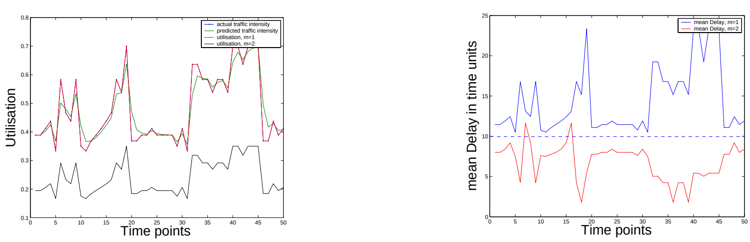
Fig. 1. Virtualised Health Services Management

providing intelligent control with optimal performance metrics that meet government targets such as cost, quality of patient care, patient treatment times, health care priorities among others. Based on control theory the main aspect of this approach is to achieve adaptation and prediction that meet service level agreements at any given time. Such a mechanism will capture and prioritise health service demands and enable services governance in a systematic way. It will also enhance the way in which information is displayed, events are correlated and filtered in order to aid in future policy development. A modelling and analysis technique which provides decision making abilities that optimise performance metrics while meeting control parameters such as policy initiatives, service priorities, cost is vital for any future eHealth system.

4 Case Study: Queueing Models in Health Care

4.1 Background

Within the research community queueing theory has been a popular approach in modelling real-world health care processes and involves waiting time and utilisation analysis, system design and scheduling in appointment systems. The distinct goals of many such analytical models has been predicting patient delay and resource utilisation, optimal resource allocation to aid decision making and reducing waiting times without greatly increasing server idleness. The main drawback of all these approaches is that they are based on offline analysis for prediction and development of static policies to meet a possible set of demands to be encountered by the system. However this approach may not be sufficient in future distributed health care systems which may require on-line, on-demand predictions and strategies to meet service and cost targets; albeit in systems with complex and/or emergent behaviour. Consider a simple example of a $M/M/m$ queue. Fig. 2 presents utilisation and service delay (response time) performance measures when the number of servers $m = 1, 2$. Though the delay is below the target of 10 time units when $m = 2$, the utilisation at the service centre is also low indicative of possible server idleness. This is not a preferred choice when resources are limited and expensive. This paper presents some promising results



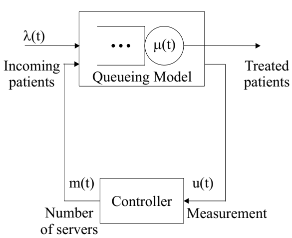
(a) Resource utilisation (b) Delay (Response time)

Fig. 2. Performance measures of a $M/M/m$ queue

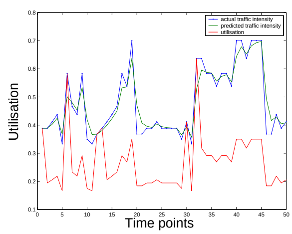
in applying optimal and feedback control with queueing theory which will be a step toward achieving this objective.

4.2 Control Framework for Optimal Resource Allocation

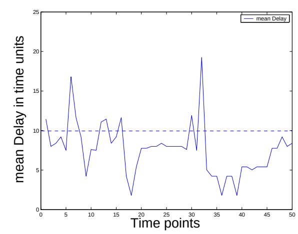
The controller designed here use a Kalman filter to dynamically allocate server resources to the service centre based on an optimal control policy with performance index J. This approach monitors and varies resource allocation. This is achieved by the controller which tracks traffic intensity, dynamically allocates resources according to a control policy and adapts to patient arrival conditions via an on-line state estimation mechanism.



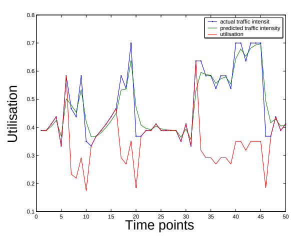
(a) Control action on a $M/M/m$ queue



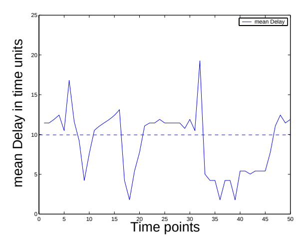
(b) Resource utilisation



(d) Delay (Response time)



(c) Resource utilisation



(e) Delay (Response time)

Fig. 3. Performance measures resulting from dynamic resource allocation in a $M/M/m$ queue

For the results presented here J is defined as a function of cost of resources and penalty for missed delay targets. The cost of resources, C_r (cost units/server) and penalty cost C_p (cost units/patient) is set at $[150, 250]$ and $[200, 250]$ for Figs. 3(b), 3(d) and Figs. 3(c), 3(e) respectively. The Kalman filter enables prediction of the traffic intensity at the next sample point as shown in Figs. 3(b), 3(c). Then the optimal resource allocation (number of servers) that keeps the cost to a minimum is obtained. The optimal number of servers reduces the mean Delay as shown in Figs. 3(d), 3(e) while the utilisation at the service centre, Figs. 3(b), 3(c), is kept higher than in Fig. 2(a). This is achieved by defining an appropriate performance index J.

Aligning Technology with the Organisation Using Focus and User Groups

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Abstract. As an IT Manager of nine years in a small healthcare organisation, which has transitioned from a minimal base of IT to fully fledged systems in place, I have discovered two structures which have helped enormously in this transition. These structures are firstly, the focus group, which looks at the IT requirements of the business, and secondly the user group, or a group of super users, which help in the day to day running of the systems. I have put together a number of lessons, which I have learnt over the years through experience of the workings of these groups, the benefits of them and the value they bring to the organisation.

1 Introduction

I am the IT Manager of the Central Remedial Clinic for the last nine years. The Central Remedial Clinic provides a range of specialised services for children and adults with physical disabilities. Its facilities and services are available to people from all over Ireland. It is a non-residential voluntary organization.

When I started my work within this organization, the technology in the clinic consisted of number of standalone PC's and an old AS400 system. This system simply collected attendance numbers for management reporting. Now, however the clinic has a network spanning five national locations, has three hundred networked PCs and uses the latest virtualisation technologies. The AS400 system has been replaced by a comprehensive MS SQL server based Patient Administration System.

This new system, which took me three years to research, source, evaluate and implement. The system needed to be flexible enough to suit the particular specific needs of our organization. Whilst the old system was bespoke, the new system needed to be a packaged one, and therefore eliminate ongoing development costs. It has now been in place for five years.

The use of a focus group, during the process of researching and sourcing the new system, provided an invaluable tool in ensuring that all the needs of the organization were met in the new system. During the implementation stage the user group of "super users" provided excellent feedback and support.

Whilst using these two structures over the years, I have collated many of the lessons, which I have learnt through experience. I also have collated the benefits and value they bring to the organization.

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2 Aligning IT and the Organisation

Simply purchasing the technology is not enough. The linkage of the organisations functions and processes with the technology it uses is critical to the success of the organisation. The use of focus and user groups brings together the gaps in knowledge between the technologists and those who the systems are designed for. On the one hand, they enable the technologists to have a better understanding of the processes that they are trying to implement. On the other hand, it enables the clinicians and administrators to have a better understanding of the limits which technology brings. This in effect aligns IT and the organisation.

3 Focus Groups

3.1 Aims

The aim of the focus group is to bring together the technology and the organisation. Whilst the aim is very clear, it will mean significantly different things from the viewpoint of the different members. This is one of the major strengths of the group. A single group should be sufficient for most small organisations but multiple subgroups could be formulated for specific projects as required.

3.2 Structure

There should be an identifiable owner of the group. They should be an enthusiastic and driven supporter of the solution been developed. It is their responsibility to keep the show on the road. If the group leader is not motivated to drive the process forward, it will be extremely difficult to get results. The group should consist of people from different levels in the organisation, clinicians, administrators, as well as middle and senior management. This gives voice to the different expectations of all of the end users. Sometimes there will be separate existing structures such as heads of department groups, which can be linked into. The group should be as small as possible with each member being there to represent a particular group. The members should be carefully chosen to ensure that they hold the respect of their colleagues they represent. The group should evaluate its structure on a regular basis.

For technology integration to be successful, it is essential that the organisation “buy-in”. It is therefore essential, that at least one member of the group is from senior management. This person should hold a position of direct line responsibility, to those using the system. Support from the higher levels of the organization is also essential. This will ensure that the system is designed with the broadest viewpoint.

3.3 Functions

Rigid sets of rules pertaining to the scope of the group are unhelpful and often lead to a reduction in the creative thinking of its members. Specific areas of work should be agreed on and prioritised. Following this the scope for these areas can be agreed upon.

3.3.1 Information Exchange

Information exchange within the group, validates the reasons for decisions made, by the IT function with the organisation. It identifies areas where the organisation requires solutions easily. The exchange of information is especially important when things go wrong. This is outlined later in the paper.

3.3.2 New Systems Procurement

The “focus group” has a pivotal role in the procurement process of new systems. It is essential that the processes, which are to be included in the system, are fully understood. Many projects have failed, due to a lack of understanding of the processes involved, and the subsequent inability of the system to deal with them. Occasionally, it is not an IT solution is not required, but a change to the underlying process. In such cases the group will ensure that the process is correct before a solution is developed for it. In cases where departments use different processes to perform the same function; these need to be unified into a standard process.

The focus group indentifies areas where proposed IT solutions can be implemented within the organisation. The broader view of the group enables the linkage to other systems, which would not have otherwise been considered.

3.3.3 Decisions

The group responsibility of decisions prevents the IT function making unilateral decisions which negatively impact the organisation. Priority, reflecting the organisations needs is also achieved.

3.4 Challenges

Unwillingness of end users to use systems, is often due to a lack of understanding in the reasoning as to why a system is in place. This is especially the case when statistical information is been collected. The buy-in from senior management, the involvement of all levels in the organisation, and the inclusion of direct line management in the group, helps to alleviate this.

Where possible, design of systems should include benefits to all the end users, ensuring that they both give to, and receive, value from the system.

Another challenge that can occur is when a long line of reasons is presented as to why the new system cannot be used. The reasons should be first collated and then examined. Many can be based on misconceptions. If this is the case, use of the system on a trial basis by those with the misconception can usually allay their fears. If the reasons are valid, they should be swiftly addressed. Eventually it will become apparent to everyone, that the list while partially valid, was mostly an expression of resistance to change.

Sometimes it just requires patience to wait for a particular set circumstance to happen to take the opportunity to highlight certain points.

3.5 When Things Go Wrong

Information exchange is one of the primary functions of the focus group when things go wrong. They facilitate the discussion of the problem from all sides, as opposed to just a technical point of view. They recognise that the problem is not just an IT issue but an issue for the complete organisation. Interim solutions can be investigated whilst the original problem is been addressed. Following this, discussion around reasons for the failure can take place in a broader context. Processes can then be put in place to reduce the risk of it reoccurring. Some of the problems that occur are not technical, however, they are laid at the door of IT management. The group is in an excellent position to recognise this rather than it turning into a game of “hot potato”.

4 User Groups

4.1 Structure

The user group consists of only one representative or “super user” within each department or functional area of the organization. This ensures that there is clarity in the communication to and from each department. The group both meets together from time to time, however its primary communication is to a specified member of the IT department. As before its members should be carefully chosen to ensure that they hold the respect of the colleagues they represent.

4.2 Aims

The aim of the user group, is to ensure that the day to day running of the system, is applied as it was designed. They train users at a local level, and are aware of changes and upgrades to the system. Being made aware of policy changes, they communicate these to their colleagues at a local level.

4.3 Functions

4.3.1 Training

When systems are first introduced, formal cascade training from the systems vendor, to the “super users” can take place. This reduces training costs, as there are substantially less users to be trained. It enables the “super user” localize training before giving it to their user base. This localization of the training needs to be carefully managed. This is to ensure that the policies, which pertain to the systems, are included in the initial training.

With existing systems, the “super user” provides training to additional staff members in a standardised manner, throughout the organization.

4.3.2 System Performance

The “super user” best judges the performance of systems. They both use the system and hear all the smaller issues which users experience. They are in a better position to have objective views on system performance and identify the main pain points.

4.3.3 Problem Solving

When problems occur, users are encouraged to report it to their local “super user”. This report is then passed up the line to the IT Department. A big advantage of this is the filtering out of smaller, solvable problems and it acts as a type of first level support. Another advantage of this is the “super users” are more in touch with their user base, and will therefore easily differentiate between the disgruntled user, and the one who has a real issue.

This gives the IT section, more time to resolve the issue, rather than fielding calls regarding it. The information exchange, between the IT function and the super users, will ensure users are aware that the problem is been given the appropriate resources.

If the problem is a result of a lack of knowledge by the user, the “super user” is in an ideal position to provide this extra training on an ad hoc basis.

Whilst users are encouraged to use this structure it is vital that they also be able to contact the IT department directly as otherwise a disconnect will occur between the users and the IT Department.

5 Conclusion

The new patient administration system was successfully implemented has now been in place for the last five years. The alignment of the organizations needs, and the new system, has been achieved through the use of the “user group” and “focus group” structures. The importance of the ongoing work of the focus group and user group continues as the needs of the organization change over time. This has been evident in new areas of the system been utilized which were not originally thought required. The length of time needed to implement the new system, through the use of these groups has proved longer than expected. However this has resulted in a better solution been achieved. The collaborative nature of the relationship between the supplier of the new system and the organization, has resulted in a better system both for the Central Remedial Clinic and for the suppliers other clients. Finally, the support from a strong IT team, who are committed to the success of the project, and who are aware of the benefits of “focus groups” and “user groups”, continue to be invaluable to the ongoing success of the new system.

Diabetes City: How Urban Game Design Strategies Can Help Diabetics

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Abstract. Computer Games are about to leave their "electronic shells" and enter the city. So-called Serious Pervasive Games (SPGs) [1] allow for hybrid – simultaneously physical and virtual - experiences, applying technologies of ubiquitous computing, communication and "intelligent" interfaces. They begin to focus on non-entertaining purposes. The following article a) presents game design strategies as a missing link between pervasive computing, Ambient Intelligence and user's everyday life. Therefore it spurs a discussion how Pervasive Healthcare focusing on the therapy and prevention of chronic diseases can benefit from urban game design strategies. b) Moreover the article presents the development and work in progress of "DiabetesCity" - an educational game prototype for young diabetics.

Keywords: Ubiquitous & Pervasive Computing; Pervasive Healthcare; Urban Design; Serious Games; Medical Documentation; Diabetes Care.

1 Introduction

Diabetes is a chronic disease likely becoming a major epidemic in the developed countries. Today 200 million live with the disease and the World Health Organization (WHO) predicts an increase to 350 million diabetics until 2025. Type 2 diabetes, which comprises 90 % of the diabetes cases, is largely the result of excess body weight and physical inactivity. Moderate changes in lifestyle, an adequate diet, more physical activity and loss of weight positively influence the therapy of type 1 and type 2 diabetes.

Documenting daily medical data is one essential part of this education. So far diabetics collect their data in so called "diabetes-diaries". These hand-written diaries are the basis for a discussion between the doctors, diabetes-assistants and the patients in order to improve the therapy set up.

Digital documentation tools, for example applications running on a mobile phone or a personal computer are already available, but hardly accepted by diabetics. Further more the documentation is mainly focused on medical aspects only. Even if the positive effects on diabetes by a sound lifestyle, e.g. healthy diet and physical activity, is proven by many studies, there is no documentation tool available so far, that detects the connection between the medical data and the daily personal behavior.

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By combining strategies of Serious Game Design with Pervasive Healthcare young patients should be motivated playfully to document their relevant data. The development of the prototype for a Medical Pervasive Game presents urban design research as an interdisciplinary working field. Addressing the relationship between urbanism and healthcare, it seeks to formulate a potential involvement of urban planners in the "design process" of prospective public healthcare projects.

2 How Ubiquitous Computing Evolves into Pervasive Games

"The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it." [2]

This famous quote by Mark Weiser gave birth to the expression of "ubiquitous computing" in 1991. Back in the 1980s Weiser identified two main issues of ubiquitous computing: 1.) The scale of microchips and 2.) The ability of microchips to localise. The second in particular is important in order to extend ubiquitous computing to the dimension of an "ambient intelligence".

Ambient intelligence environments, which so far are restricted to buildings and houses, combine "three recent key technologies: Ubiquitous Computing, Ubiquitous Communication and Intelligent User Interfaces." [3]

The invention of global positioning systems (GPS) and their availability in small, mobile devices enables an adaptation of intelligent ambience environments to the whole space of our cities. This is an important point for pervasive healthcare, because patients' everyday life does not only take place in the boundaries of the flats and houses they are living in. But what are the prerequisites for a so-to-call "intelligent ambient city"?

At this point game design seems to be one missing link in the field of human-machine interaction. By conceiving and defining rules and structures that result in experience for players, the design of the *game play* becomes an interesting tool of designing the actual use of technology, in our case: parts of the medical therapy. We have to keep in mind this idea when we talk about projects for chronic patients, who often have to integrate plenty of medical "gadgets" in their everyday life.

3 Serious Games and Pervasive Healthcare

The term "serious game" has been defined by the "Serious Games Initiative" founded by the Woodrow Wilson International Center for Scholars as digital games with non-entertainment purposes such as health care, security, management or learning in 2002. Since 2004 the sub-group "games for health" focuses on "the impact games and game technologies can have on health care and policy."[4] Current trends include video games for rehabilitation and therapy issues and the emerging field of "Exergaming", motivating players for more physical activity.

Developing an educational game for chronic patients like diabetics we seek for game design strategies, which integrate the *gameplay* into the everyday life of its players. A new generation of computer games, called "Serious Pervasive Games" therefore overlay the physical space with a virtual game zone. "They [pervasive games] not only serve as a new type of gaming, but also as a new form of using and experiencing the city. In pervasive games the city transforms into a playground that can be played every time and everywhere. And this functional assignment does not depend any longer on the building structures but on the available technology."[5] Several prototypes for Serious Pervasive Games (SPGs) have been developed in the fields of health care, security, tourism, management or learning in the last ten years. [6]

The first pervasive serious game that focuses on "the relationship between art, technology and health" is the *Mixed Reality Game* "Ere Be Dragons" by Active Ingredient at University of Nottingham in the UK. "The player wears a heart rate monitor, and inputs his or her age into a pocket PC." An optimal heart rate is calculated and the player starts to walk where ever or however he or she wishes. During the walk an on-screen landscape is built, which uses GPS and corresponds to the real environment surrounding the player and his or her measured heart rate. If players do well for example, adequately exercising their hearts, the landscape flourishes, "while overexertion leads to the growth of a dark, forbidding forest." [7]

Apart from that scientific and artistically approach, doctors and managers in the public health sector begin to see that healthcare is no longer restricted to the hospital or the clinician's practice. Researchers use new technical possibilities and the growing interest of users in collecting private physical data. The Aarhuis-based "Centre of Pervasive Healthcare" (CfPH) works on several case studies for a so-called "HealthyHome". [8] Pervasive Healthcare provides a technical and mental support for patients in their living space in special situations (e.g. for the period of a pregnancy, for elderly or isolated people).

The research on Medical Pervasive Games (MPGs) works on an extension of the user's action-field from the scale of a "healthy home" to the scale of the city and therefore to support patients in their everyday life environment. MPGs seek to develop the potentials of serious games for the education and motivation of people in prospective healthcare and prevention projects.

4 Prototyping a Game for Diabetics

The MPG for Diabetics is aimed at insulin-depending young people with type-1 and type-2-diabetes. It is a prerequisite for the game that users are sufficiently introduced into the basic knowledge of their disease by doctors, nurses and diabetes assistants. In general, patients receive the first brief at the beginning of their disease. Patients learn under clinical circumstances how the disease affects their body, when and how much insulin they need and what an appropriate diet should look like. Patients are instructed how to use their personal technical aids, such as insulin pump or pen, the measurement system and how to do documentation of all the important parameters.

After this period the patients return to their everyday lives facing its complexity of requirements and possibilities. The patients often realize that their therapy was adjusted under the so-called "white-coat-effect". In this point the MPG can support patients as an extension of the clinical introduction into their everyday routine. We focus on children and young adults with diabetes, because in their situation it is of particular importance to combine an active lifestyle with a well-adjusted diabetes treatment to avoid the long-term complications of the disease.

4.1 Objectives – The Spatial Diary

The MPG aims to stimulate a “Spatial Diary”, which extends the medical documentation to the factor of the “City”. Because the positive effect of lifestyle factors on diabetes is proven, aspects of patient’s every day life in their every day environment should be considered in their medical documentation. With the implementation of Serious Game Design, a new strategy of motivation and education should be applied to the therapy of chronic diseases. The Medical Spatial Diary should help to visualize deeply inscribed behavior, such as physical inactivity, stress or inadequate nutrition - factors, which have a grave impact on the patient’s sugar levels. As a result the Medical Spatial Diary could serve as an active therapy tool. Patients and doctors are able to discuss therapy and behavioral improvements on a visual basis combining the medical data with the daily activities and their environments.

4.2 Medical Game Design Concept

Therefore our institute develops the serious game design concept “DiabetesCity - Collect Your Data”. Children and Young People with diabetes are playfully motivated to document as much as possible of their medical data in their everyday life for a period of 1 week. Early stages of the game design concept provide teams of two players seeking to find and to reveal certain points of interest in the City of Stuttgart. Each team consists of one boy or girl with diabetes and one of his or her friends. The two player receive a camera phone and GPS-featured glucose monitoring system when starting the game. The teams get hints by solving puzzles and doing small exercises - e.g. by interacting with the system.

The more data the diabetic collects, for example by measuring his or her blood sugar levels or taking pictures of an activity, the more question marks on the virtual maps are deleted and turn into “place marks” of the Spatial Diary. The non-diabetic partner can achieve details for the team by answering questions about the disease. By including this feature we hope to encourage social interactivity between the players and to improve mutual understanding between “patients” and their entourage.

4.3 Realisation / Work in Progress

Urban Game Design strategies as interactive storytelling and community-based communication between users shall be applied on “DiabetesCity” in order to motivate the kids. For the game design concept we work closely together with the doctors from the Centre for Diabetes Care and Education at the Olgahospital, Stuttgart. Currently we are presenting working-models and mock-ups of the prospective game in very early stages to the kids and the future end-users. Pervasive Games can be simulated and prototyped as “augmented” board games. The early involvement and participation of the patients and “players” is an essential part of the design process.

In cooperation with mobile computing scientists we are working on an interconnection between a standard blood glucose monitoring system, GPS based positioning and the camera of the mobile phone. A standard GPS receiver (65 x 46 x 17 mm) for example can be attached to the medical device and is tracking the GPS coordinate of its user every 2 seconds. Date, time and position are saved on an in-built flash memory program and can be read into the PC via Bluetooth or via USB wire afterwards.

Data of the glucose monitoring system and the camera phone can be transferred the same way. The main item therefore is the development of an application that combines data retroactively, for example every night. As a result of this procedure the data of the three devices (blood glucose level, position and picture) can be imported to an internet-based “earth browser” such as Google maps or Google earth. Users just connect their “gadgets” to PC and open his or her earth browser. The application easily pops up with some of the common “place marks” providing information about time, measured glucose level and the activity illustrated by a picture or a remark. These “Spatial Diaries” can be shared with other players or the doctor. They build a visual basis for optimizing diabetes therapy and making suggestions for changing lifestyle factors for the patients. Therefore they work as an extension to the existing diabetes management systems.

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Potentials of Web 2.0 for Diabetes Education of Adolescent Patients

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Abstract. Diabetes is a very common chronic disease which produces complications in almost all body organs and consumes a huge amount of the health budget. Although education has proved to be useful in diabetes management, there is a great need to improve the availability of these courses for the increasing number of diabetic patients. E-learning can facilitate this service, but the current education system should be tailored towards e-learning standards. Amongst diabetic patients, adolescents as computer natives are suggested as the best target to e-learning diabetes education. With regards to its features, Web 2.0 can be a very good technology to build a framework for diabetes education and consequent evaluation of this education.

Diabetes Mellitus (DM) is one of the major chronic diseases characterized by high blood glucose level. Diabetes is classified by two main types based on the pathogenic process which leads to hyperglycemia. Type I is caused by complete or near total deficiency of insulin and type II is caused by heterogenous set of factors such as variable degrees of insulin resistance, impaired insulin secretion, and increased glucose production. Reports by Diabetes UK which use Yorkshire and Humber Public Health Observatory (YHPHO) model, a population-based model for both diagnosed and undiagnosed diabetes, indicated that the prevalence of diabetes has risen from 3.54% to 3.66% between 2006 and 2007, due to the 0.33% incidence rate of diabetes [1, 2] and increased efficacy of diagnostic procedures.

The Diabetes Control and Complications Trial (DCCT) provided definitive proof that reduction in chronic hyperglycemia can prevent many of the early complications of type I DM. The UKPDS research proved the similar result in type II of diabetes.

Adolescence is a critical period in diabetes which is characterised by profound alterations in the metabolism as a result of physiological adaptations during puberty. This feature of adolescence commonly manifests as a deterioration of glycemic control. Prevalence of both type I and type II diabetes has increased amongst young people of less than 18 years of age.

Due to the element of personal responsibility involved in most procedures of diabetes care, such as carbohydrate intake control, blood glucose monitoring, insulin injection in type I diabetes and also diet control and weight watch in type II, education does play an important role in this process. The educational requirement is also emphasized by National Institute for Clinical Excellence (NICE) guidance on diagnosis and management of type I diabetes in children and young people. National

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Institute for Clinical Excellence (NICE) defines structured education as “a planned and graded programme that is comprehensive in scope, flexible in content, responsive to an individual’s clinical and psychological needs, and adaptable to his or her educational and cultural background.” Also standard 3 of the National Service Framework (NSF) states that: “all children, young people and adults with diabetes will receive a service which encourages partnership and decision-making, supports them in managing their diabetes and helps them to adopt and maintain a healthy lifestyle”.

Adolescence is a period for learning independence and increasing self-esteem. This formative period is the optimal time for educating patients to accept their own responsibility for care.

The statistics show that the coverage of education for young patients with diabetes is not satisfactory. The results of a survey conducted by Diabetes UK shows that only 5.5% of diabetic children have received structured education about their disease [3] which is less than the 11% coverage of structured diabetes education in all diabetic patients in the UK [4]. The most limiting factors were lack of courses on offer or inappropriate timing and/or location of the course.

There were several successful trials in application of Internet based education system for this purpose such as the Informatics for Diabetes Education and Telemedicine (IDEATEL)[5] project in the USA and the patient-orientated diabetic education management (POEM)[6] project in Taipei which demonstrated the benefits of this tool for diabetes education. Also Bell J A et al designed a pre-test post-test project (Brainfood) [7] and showed the effectiveness of online diabetes education. These methods can facilitate diabetes education by increasing availability of the course as 61% of UK households have access to the Internet [8].

E-learning programs can be self managed which helps learners to arrange courses based on their personal schedules. The other problem concerning current education programmes is highlighted by Ko et al.[9] in a follow-up study, who showed that the effects of these education programs are limited to under one year. Some previous scholars such as Rosenstock have suggested the requirement for reinforcement of education programs [10].

Today’s adolescents are considered to be a computer-native generation. They are more familiar with computer technology compared to previous generations and have the ability to adopt this technology much more easily.

According to Technology Mediated Learning (TML) theory of Dr Alavi [11] to increase the effectiveness of an e-learning system two tasks should be performed:

1. Enriching the delivery medium
2. Increasing the time and amount of interaction with users.

Web 2.0 can be characterized as a group of economically, socially, and technological improvements in attitudes, tools, and applications that allow the web to become the next platform for communication, collaboration, community, and cumulative learning.

Generally this concept increases the level of access for users to enrich the educational content on the web and for this reason it is considered a “Read-Write” version of web versus the previous system in which users were only allowed to “Read” the content provided by webmasters and web content providers.

Web 2.0 has specific features which can provide the requirement for TML model. It benefits from the Rich Internet Application (RIA) concept which enriches the delivery medium. The "Web as a platform" concept of Web 2.0 will allow for building a framework for users to interact more with the system, upload their own data and receive personalized education based on their requirements and preferences.

Additionally this system can be used to conduct surveys about satisfaction levels of users with the system as this is considered as a major factor reflecting the perceived effectiveness of the system.

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Induction for Radiology Patients
(Invited Paper)

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Abstract. This paper represents the implementation of an inductive learning algorithm for patients of Radiology Department in Hacettepe University hospitals to discover the relationship between patient demographics information and time that patients spend during a specific radiology exam. ILA has been used for the implementation which generates rules and the results are evaluated by evaluation metrics. According to generated rules, some patients in different age groups or birthplaces may spend more time for the same radiology exam than the others.

Keywords: Medical Decision Making, Radiology Information System, Radiology Data Mining, Knowledge Extraction.

1 Introduction

Clinical information systems have accumulated large quantities of information about patients and their medical conditions. A radiology information systems(RIS) is a kind of clinical information system and provides many components of functions. In these systems, thousands of images, as well as a wealth of detailed ordering and demographic data, and a text report from the radiologist are stored and managed.

The activities in a radiology department importantly depends on workflow and consists of some multistep processes:

- Radiology examination request is booked electronically at Hospital Information System(HIS) terminal in a referring department and contains patient demographics and examination.
- The patient applies the radiology department for examination appointment
- The secretary schedules the examination, depending on the scheduled modality.
- The patient arrives for the scheduled examination, he/she is checked in at the reception
- The patient is examined
- Radiologist interprets the examination
- The exam report is generated.

The examination duration from request until report generation is a measure of efficiency of radiology department and it directly affects on departmental quality,

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clinical outcomes and decision making. If the duration is reduced, clinicians can receive the results and treat the patients much quicker. Therefore, short duration saves time, money, and it helps improve the quality and timeliness of patient care.

In order to improve productivity and efficiency in radiology workflow, some hidden factors affecting on long durations should be discovered in data stored in the radiology information system. In this study, the techniques of machine learning is applied to discover hidden knowledge in the Radiology information system used in Hacettepe University Hospital. ILA software is used that is a new inductive algorithm for generating a set of classification rules for a collection of training examples [1].

Data set is created according to ILA input file format and the algorithm is applied on this dataset.

1.1 Problem Definition and Algorithm Task Definition

Knowledge is one of the most important assets of healthcare organizations and it is also used by administrators to improve the quality of service [2].

Like many health centers, Radiology Department of Hacettepe University(HU) Hospitals uses information system to collect and store medical data. These data consists of patient demographics, radiological exam information and appointment details. Despite the large amount of data in this system, there is a lack of useful knowledge.

The radiology department of HU Hospitals needs to use data mining techniques and focuses on these objectives such as:

- To optimise the allocation of human and material resources
- To improve radiologicial services
- To find the relationships between patient demographics and radiology exam and turnaround time

Aim of this study is to search for hidden patterns and to discover relationship between patient demographics and time that patients spend during radiology exams.

Our hypothesis in this study is that "is patient demographics information such as age, sex and birthplace are related to the exam duration in Radiology Department?" Our study finds a answer for this question.

1.2 Inductive Inferencing Algorithms

Inductive inference is the process of taking a series of examples or observations and generating an explanation for the behaviour observed. This study uses a data-driven method attributable to Tolun et al. [1]. Inductive Leaning Algorithm, or ILA in short, generates a set of classification rules for a collection of training examples. The algorithm works in an iterative fashion, each iteration searching for a rule that covers a large number of training examples of a single class. Having found a rule, ILA removes those examples it covers from the training set by marking them and appends a rule at the end of its rule set. In other words our algorithm works on a rules per- class basis. For each class, rules are induced to separate examples in that class from examples in all the remaining classes. This produces an ordered list of rules rather than a decision tree as used by ID3 and other similar algorithms [3].

The Inductive Learning Algorithm(ILA) consists of these steps;

Step 1: Partition the table which contains m examples into n sub-tables. One table for each possible value of the class attribute (* steps 2 through 8 are repeated for each sub-table *)

Step 2: Initialize attribute combination count j as j = 1.

Step 3: For the sub-table under consideration, divide the attribute list into distinct combinations, each combination with j distinct attributes.

Step 4: For each combination of attributes, count the number of occurrences of attribute values that appear under the same combination of attributes in unmarked rows of the sub-table under consideration but at the same time that should not appear under the same combination of attributes of other sub-tables. Call the first combination with the maximum number of occurrences as max-combination.

Step 5: If max-combination = $\emptyset$, increase j by 1 and go to Step 3.

Step 6: Mark all rows of the sub-table under consideration, in which the values of max-combination appear, as classified.

Step 7: Add a rule to R whose left hand side comprise attribute names of maxcombination with their values separated by AND operator(s) and its right hand side contains the decision attribute value associated with the sub-table.

Step 8: If all rows are marked as classified, then move on to process another sub-table and go to Step 2. Otherwise(i.e., if there are still unmarked rows) go to Step 4. If no sub-tables are available, exit with the set of rules obtained so far [1].

ILA is an algorithm for extracting production rules from collection of examples. An example is described in terms of a fixed set of attributes, each of with its own set of possible values.

ILA-2 is an extension of ILA with respect to the modifications. The first modification is the ability to deal with uncertain data and the second is a greedy rule generation bias that reduces learning time at the cost of an increased number of generated rules.

1.3 Description of the ILA Algorithm with a Running Example

In describing ILA we shall make use of a simple training set. Consider the training set for disease classification given in Table 1, consisting of seven examples with three attributes and the class attribute with two possible values. The first step of the algorithm generates two sub-tables which are shown in Table 2.

Let us trace the execution of the ILA algorithm for this training set. After reading the object data, the algorithm starts by the first class(yes) and generates hypothesis in the form of descriptions as shown in Table 4. A description is a

Table 1. Disease classification training set

Example No	Age	Blood Pressure	Cigarette Use	Disease (Class)
1	25	High	Not used	yes
2	37	Normal	Seldom	no
3	37	Normal	Frequently	yes
4	53	Normal	Seldom	no
5	53	Low	Always	yes
6	53	Normal	Always	no
7	53	Low	Frequently	yes

Table 2. Sub-table 1 of The Training Set Partitioned According to Decision classes

Example no.		Age	Blood Pressure	Cigarette Use	Disease Decision
Old	New				
1	1	25	High	Not used	yes
3	2	37	Normal	Frequently	yes
5	3	53	Low	Always	yes
7	4	53	Low	Frequently	yes

Table 3. Sub-Table 2 of The Training Set Partitioned According to Decision classes

Example no.		Age	Blood Pressure	Cigarette Use	Disease Decision
Old	New				
2	1	37	Normal	Seldom	no
4	2	53	Normal	Seldom	no
6	3	53	Normal	Always	no

Table 4. The first set of description

No	Description	True Positive	False Negative
1	Age=25	1	0
2	Blood Pressure=High	1	0
3	Cigarette Use=Not used	1	0
4	Age=37	1	1
5	Blood Pressure=Normal	1	3
6	Cigarette Use=Frequently	2	0
7	Age=53	2	2
8	Blood Pressure=Low	2	0
9	Cigarette Use=Always	1	1

conjunction of attribute-value pairs; they are used to form the left hand side of rules in the rule generation step.

For the combination Age the attribute value “25” appears in Table 2 but not in Table 3, so the value of max-combination becomes “25”. Since other available attribute values “37” and “53” appear in both Table 2 and Table 3 they are not considered at this step. The occurrence of Age attribute value “25” is noted as one times and next combination is evaluated with max-combination set to “Low”. For combination Blood Pressure we have “High” with an occurrence of one times and “Low” with an occurrence of two times. Continuing further with combination Cigarette Use, we have “Not used” with one occurrence and “Frequently” with two occurrences. At the end of step 4, we have Blood Pressure attribute value “Low” and Cigarette Use attribute value “Frequently” marked with maximum number of occurrences. Here either of the attribute values can be selected, because both of them can classify the same number of training examples. The algorithm always selects the first one(i.e. “Low” in this case) by default, and this will make max-combination to keep its current value of “Low”. Rows 3 and 4 are marked as classified in Table 2, since the value of max-combination is repeated in these two rows, the following production rule(Rule 1) is extracted:

Rule 1:
IF Blood Pressure is Low THEN the disease decision is yes.

Now, ILA algorithm repeats step 4 through step 8 on the rest of the unmarked examples in sub-table 2(i.e. rows 1 and 2). By applying these steps again we have “25” attribute value of Age, “high” attribute value of Blood Pressure, “Not used” and “Frequently” attribute values of Cigarette Use occuring once. Since the number of occurrences are the same, the algorithm applies the default rule and selects the first one considered(i.e. “25” attribute value of Age). Then the following rule (rule 2) is added to the rule set:

Rule 2:
IF Age is 25 THEN the disease decision is yes.

He first row in sub-table 1 is marked as classified and steps 4 and 8 are applied again on the remaining row(i.e. the second row). Here we have “Frequently” attribute value of Cigarette Use occuring once, so the third rule is extracted:

Rule 3:
IF Cigarette Use is Frequently THEN the disease decision is yes.

By marking the second row as classified all of the rows in sub-table 1 are now marked as classified and we proceed on to sub-table 3. The “Seldom” attribue value of Cigarette Use occurs twice in the first and second rows in sub-table 3. So,these two rows are marked as classified and Rule 4 is appended to the rule list.

Rule 4:
IF Cigarette Use is Seldom THEN the disease decision is no.

In the remaining row in sub-table 3(i.e. the third row) we have Age attribute with a value of “53” that appears also in sub-table 1. So according to the algorithm this cannot be considered. The same applies to "Normal" value of Blood Pressure and "Always" value of Cigarette Use attributes. In this case, ILA increases j by 1, and generates 2-attribue combinations, Age and Blood Pressure, Age and Cigarette Use, and Blood Pressure and Cigarette Use. The first and third combinations satisfy the conditions as they both appear in sub-table 3 but not in sub-table 2 for the sam attributes. The "53 always" value of Age and Cigarette Use combination is ignored because it already appears in sub-table 2. according to this, we can choose either the first of the third combination but the default rule allows us to select the first one. The following rule(Rule 5) is extracted and the third row is sub-table 3 is marked as classified:

Rule 5:
IF Age is 53 AND Blood Pressure is Normal THEN the decision is no.

Now, since all of the rows in sub-table 3 are marked as classified and no other sub-table is available, the algorithm terminates [1,4].

Java implementation of ILA-2 has the following features:

- user interface which makes all algorithm parameters accessible
- options saved to disk
- reading data from relational tables
- saving rules to relational tables
- possibility of running cn2 algorithm
- simple discretization support

2 Experimental Evaluation Methodology

Dataset that is analyzed by using ILA algorithm is collected from Radiology Information System used in HU Hospitals by using SQL queries. A brain MRI (Magnetic Resonance Imaging) is selected as a specific exam to create a meaningful dataset. 2844 patients who undergone a brain MRI exam were selected. The attributes of patients' birthplace, gender and birthdate were directly collected from database. The birthplaces were categorized according to the biggest cities and regions in Turkey. Age is calculated for each patient and categorized (Table 5). The duration is selected as a class function. This value is calculated for 2844 patients and the mean value of duration is found. If the duration value of tuple is bigger than mean, it is assigned long, otherwise short (Table 6). Therefore, two classes were obtained. The dataset consists of four attributes and two classes which are short or long. There are 2021 short and 823 long instances in the dataset. Table 8. shows the attributes and categorized values. Some instances of the dataset are seen at Table 8. The attributes are patients' birthplace, gender and birthdate. The classes in this dataset are short or long. There are 2021 short and 823 long instances. ILA accepts exactly the same input data file formats as C4.5, consisting of a name-file, a data-file, and an optional test-file. In addition to flat files, ILA can read data from relational database tables, and

Table 5. Age Categories

AGE	CATEGORY
$0-14$	CHILD
$15-24$	YOUNG
$25-64$	ADULT
$65 \leq$	SENIOR

Table 6. Duration Categories

DURATION (Mean=31 days)	CATEGORY
$\leq$ Mean	SHORT
$>$ Mean	LONG

Table 7. Attributes and Values

ATTRIBUTES	VALUES
BIRTHPLACE	ANKARA, IZMIR, ISTANBUL, AEGEAN, BLACKSEA, CENTRAL ANATOLIA, MARMARA, MEDITERRANEAN, EASTEARN ANATOLIA, SOUTHEAST ANATOLIA
GENDER	M,F
AGE	CHILD,YOUNG, ADULT, SENIOR
DURATION (Class)	SHORT, LONG

Table 8. Some Instances of The Dataset

BIRTHPLACE	GENDER	AGE	DURATION
BLACKSEA	M	SENIOR	LONG
AEGEAN	F	YOUNG	SHORT
ANKARA	F	CHILD	SHORT

save generated rules to relational database tables. In this study two input files is created. These are patientbrain.data and patientbrain.names that conform to ILA input data file formats.

Patientbrain.names and Patientbrain.data files are seen in Tables 9. and 10.

Table 9. The view of Patientbrain.names

SHORT,LONG	
BIRTHPLACE	: AEGEAN,ANKARA,IZMIR, ISTANBUL,BLACKSEA,CENTRALANATOLIA, MARMARA,MEDITERRANEAN, EASTEARNANATOLIA, SOUTHEASTANATOLIA
GENDER	: M,F
AGE	: CHILD,YOUNG,ADULT,SENIOR

Table 10. The view of Patientbrain.data

AEGEAN,M,CHILD,SHORT.
AEGEAN,M,CHILD,SHORT.
AEGEAN,M,CHILD,SHORT.
AEGEAN,M,CHILD,SHORT.
AEGEAN,M,CHILD,SHORT.
AEGEAN,M,CHILD,SHORT.
AEGEAN,M,CHILD,SHORT.
AEGEAN,M,CHILD,SHORT.
AEGEAN,M,CHILD,SHORT.

3 Results

After applying the ILA algorithm for patientbrain dataset, some rules are generated. The algorithm classified 2844 examples and generated 22 rules. The results are;

Number of examples 2844,
Number of classes 2,
Number of attributes 3
Number of rules 22

If GENDER =M and BIRTHPLACE =ANKARA then SHORT.
If AGE =CHILD and BIRTHPLACE =ISTANBUL then SHORT.
If AGE =YOUNG and BIRTHPLACE =AEGEAN then SHORT.
If AGE =SENIOR and BIRTHPLACE =IZMIR then SHORT.
If AGE =CHILD and BIRTHPLACE =ANKARA then SHORT.
If AGE =SENIOR and BIRTHPLACE =AEGEAN then SHORT.
If AGE =SENIOR and BIRTHPLACE =ANKARA then SHORT.
If AGE =YOUNG and BIRTHPLACE =MARMARA then SHORT.
If GENDER =M and BIRTHPLACE =IZMIR then SHORT.
If AGE =ADULT and BIRTHPLACE =IZMIR then SHORT.
If AGE =CHILD and BIRTHPLACE =IZMIR then SHORT.
If AGE =SENIOR and GENDER =F and BIRTHPLACE =ISTANBUL then SHORT.

If AGE =ADULT and GENDER =F and BIRTHPLACE =ISTANBUL then SHORT.
If AGE =CHILD and BIRTHPLACE =BLACKSEA then LONG.
If AGE =CHILD and BIRTHPLACE =CENTRALANATOLIA then LONG.
If AGE =ADULT and BIRTHPLACE =BLACKSEA then LONG.
If AGE YOUNG and BIRTHPLACE =BLACKSEA then LONG.
If AGE =ADULT and BIRTHPLACE =SOUTHEASTANATOLIA then LONG.
If AGE =YOUNG and BIRTHPLACE =SOUTHEASTANATOLIA then LONG.
If AGE =CHILD and BIRTHPLACE =MARMARA then LONG.
If AGE =CHILD and GENDER =F and BIRTHPLACE =AEGEAN then LONG.
If AGE =ADULT and GENDER =M and BIRTHPLACE =AEGEAN then LONG.

According to the results, some interesting rules are obtained from the dataset. For example, the rule, If AGE =CHILD and BIRTHPLACE =BLACKSEA then LONG, indicates that if a patient's birthplace is in the Blacksea region, the duration of the medical exam is long.

The number of rules is considered as an evaluation parameter because the main aim is to produce the minimum number of rules as possible that can classify all of the examples in the training set. The second parameter that has great significance in the evaluation process of inductive learning systems is the capability of the system to classify as much unseen examples as possible [1].

Accuracy is the other important issue for the classification applications. It is the percentage of examples in the test set that are classified correctly. There are some evaluation metrics such as TP(True Positive), FN(False Negative), FP(False Positive) and TN(True Negative) for evaluation classification applications. The true positive and True negative are correct classifications. A false positive is the class is incorrectly predicted as positive when it is in fact negative. A false negative is when the class is in fact positive.

In order to normalize the score, a simple metric is obtained from the total number of positive instances, P, and negative instances, N as

$$(TP + TN)/P + N \tag{1}$$

Considering the results, the classifier's performance should be evaluated in terms of the error rate.

Output of evaluation metrics for the patientbrain dataset is shown in Table 11 In ILA Inductive Learning algorithm, for some applications, part of the available data is reserved as a test set to evaluate the classifier produced. If there is one, the test set appears in the file filesystem.test, in exactly the same format as the data file [4]. In this study, the classifier is tested by using this feature and Table 12 shows these results.

According to Table 9, 648 instances of the dataset are used to test the classifier produced and 334 of them is classified as a 0 class, 314 of them is classified as a 1 class. Every instance in the test file is correctly classified. Therefore, there is no wrong classification. Uncovered instances are the rest of the dataset that are not used for testing.

Table 11. ILA Results

Rule No	TP	FN	Error
1	195	0	0.0
2	19	0	0.0
3	18	0	0.0
4	17	0	0.0
5	12	0	0.0
6	12	0	0.0
7	10	0	0.0
8	10	0	0.0
9	6	0	0.0
10	3	0	0.0
11	2	0	0.0
12	25	0	0.0
13	5	0	0.0
14	111	0	0.0
15	86	0	0.0
16	37	0	0.0
17	37	0	0.0
18	18	0	0.0
19	15	0	0.0
20	8	0	0.0
21	1	0	0.0
22	1	0	0.0

Table 12. Evaluation of the Classifier

Class	True Classification	Wrong Classification	Uncovered
0	334	0	1687
1	314	0	509

ILA-2 is an extended version of ILA and has additional features. These features;

– A faster pass criterion reduces the processing time and called fastILA.
– PF(Penalty Factor) is an evaluation metric utilized in ILA2.
– Different feature subset selection(FSS). With FSS, the search space requirements and the processing time will probably be reduced due to the elimination of irrelevant attribute value combinations at the very beginning of the rule extraction process [5].

As basic ILA is applied on our dataset, additional evaluation features of ILA-2 are not used.

4 Discussion

This study provides specific information obtained from administrative data of Radiology Department in HU Hospitals. Although, today many machine learning applications are performed to discovery hidden knowledge from healthcare data, these studies are usually based on radiological images and medical diagnostics. Considering this kind of researches, there is no previous published study using learning algorithm to knowledge discovery from administrative data of radiology department.

Since hospitals and clinics keep large administrative data, these data plays an important role for quality assurance of medical care and can be used to highlight practices embedded in the organization, or reveal interesting patterns among patients [6]. For example, our study reveals some hidden knowledge in radiology department. According to some rules obtained with ILA Algorithm, some patients from Southeastern Anatolia region which is undeveloped and rural area in Turkey spend more time for radiology processes in the hospital. On the other hand, other patients from big and developed cities such as Istanbul and Ankara spend less time for same exams.

The Southeastern Anatolia region in Southeast Turkey faces many of the problems that are typical of underdeveloped regions in the world. Compared with the rest of Turkey, the region has higher infant mortality, higher unemployment rates and lower literacy rates due to less access to health care and education. According to Ministry of National Education statistics, the literacy rate in the region is %68.8 [7]. The region's economy is based largely on agriculture, but productivity historically has been low. In order to solve the region' problems, Turkish Government launched The Southeastern Anatolia development Project in 1989. The project is a regional development project aiming at the full-fledged socioeconomic development [8].

The knowledge extracted with our study indicates that cultural,educational and regional factors of patients affect on the workflows in the hospitals. Radiology management should utilize our study results and define some new policies to provide time saving for patients living in rural areas.

5 Related Work

Many machine learning applications are being performed in hospital information systems to discover some hidden knowledge. In some studies, association rules are used and patient behaviors are examined to find interesting patterns among complex behaviors in the national wide health insurance data. According to results, some factors affecting on patient visits such as age, sex, rate of utilization, chronic diseases, mental disorders are discovered [9].

Data mining techniques is also used in healthcare management. Classification based data mining techniques such as Rule based, decision tree and Artificial Neural Network are frequently used for the data modeling of healthcare applications, executive Information System for Healthcare, forecasting treatment costs and demand of resources, anticipating patient's future behavior given their history and so on [9,10]. The other data modeling is used to predict whether the person is over drink-driving limit based on the data obtained from attributes for alcohol measurement such as age, sex, mass, tobacco use, height, meal(empty stomach, lunch, full) amount of alcohol and so on. Some rules are obtained [11].

Patient demographics information is generally analyzed for length of stay in the hospital and hospital related expenses. These measures are two important indicators of effective health service.In some studies, neural prediction models are used to predict the duration of stay in the hospital and hospital related expenses using demographic, environmental and hospital related factors and identify the profiles of the patients in various segments which will help in policy formulation. The data is obtained from National Sample Survey Organization(NSSO) and the duration of hospital stay and the expenditure are the two variables selected for prediction. After applications, some interesting results are discovered:

- The long duration segments have higher percentage of patients belonging to older age groups(40 years and above) where as the shorter duration segments have younger patients.
- The patients in the urban sector spend more number of days in the hospital as compared to their counter parts in the rural sector.
- The consumption of items such as alcohol, tobacco and smoking habit appear to have an impact on the stay in the hospital.
- Public hospitals appear to attract longer stay where as private hospitals attract shorter stay [12].

6 Conclusion

Healthcare domain has a big amount of data and usually many healthcare centers focus on only the implement and maintain of information systems to handle daily works. However, there is a need of knowledge that obtained from stored in data repositories in hospitals or medical centers to plan the future and to increase the productivity [10,11,12,13]. For this reason, hospital managements should consider the importance of data mining or machine applications to provide better quality healthcare services.

Despite the rich of healthcare data, many useful information is invisible in hospital and clinical information systems. Radiology Information systems are one of the big resources for knowledge discovery. In this study, relationships between patients demographics and exam duration in Radiology Department in HU Hospitals are analyzed and useful information is obtained. In the future, other hypotheses related to radiology services can be analyzed and interpreted to improve the efficiency and productivity of this department.

This paper presents a machine learning application for the patient dataset. ILA algorithm is used and evaluated to discovery hidden patterns and to search relationship between patient demographics and time that patients spend during the specific radiology exam. This algorithm extracted some hidden knowledge from this dataset by generating the rules. Considering the results, some patients in different age groups or different birthplace regions may spend more time for same radiology exam than the others.

Radiology Department of Hacettepe University hospitals should take into account this information and search new solutions to decrease the duration of exams for different patients. For example, a collaborative team should be assigned for the patients from rural areas. When the patients come to the hospital, a staff should assist them and they can easily get information about the hospital processes and the locations they have to visit. With these assisting service,the patients can be informed about hospital workflow and should not spend much time to receive healthcare services.

In conclusion, this study positively affects on the future plans and resource management of Radiology Department in HU Hospitals [14].

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