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Ambient Assistive Health and Wellness Management in the Heart of the City

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Preface

We are living in a world full of innovations for the elderly and people with special needs to use smart assistive technologies and smart homes to more easily perform activities of daily living, continue social participation, engage in entertainment and leisure activities, and to enjoy living independently. These innovations are inspired by new technologies leveraging all aspects of ambient and pervasive intelligence with related theories, technologies, methods, applications, and services on ubiquitous, pervasive, AmI, universal, mobile, embedded, wearable, augmented, invisible, hidden, context-aware, calm, amorphous, sentient, proactive, post PC, everyday, autonomic computing from engineering, business and organizational perspectives. In the field of smart homes and health telematics, significant research is underway to enable ageing and disabled people to use smart assistive technologies and smart homes to foster independent living and to offer them an enhanced quality of life.

A smart home is a vision of the future where computers and computing devices will be available naturally and unobtrusively anywhere, anytime, and by different means in our daily living, working, learning, business, and infotainment environments. Such a vision opens tremendous opportunities for numerous novel services/applications that are more immersive, more intelligent, and more interactive in both real and cyber spaces.

Initiated in 2003, the International Conference on Smart Homes and Health Telematics (ICOST) has become the premier forum for researchers, scientists, students, professionals, and practioners to discuss and exchange information and ideas on the current advances in enabling technologies coupled with evolving care paradigms to allow the development of novel applications and services for improving the quality of life for ageing and disabled people both inside and outside of their homes. Each year ICOST has a specific theme. The theme of ICOST 2003 was “Independent Living for Persons with Disabilities and Elderly People.” The theme for ICOST 2004 was “Towards a Human-Friendly Assistive Environment.” ICOST 2005 focused on “From Smart Homes to Smart Care.” For ICOST 2006, it was “Smart Homes and Beyond” and ICOST 2007 had the theme of “Pervasive Computing Perspectives for Quality of Life Enhancement.” Last year the theme of ICOST 2008 was “Gerontechnology: Enhancing the Quality of Life for Rural Elders.”

This year the conference was organized around the major theme of “Ambient Assistive Health and Wellness Management in the Heart of the City” seeking to address the latest approaches and technical solutions in the area of smart homes, health telematics, and emerging enabling technologies with a special emphasis on presenting the latest results in the successes of real deployment of systems and services.

We are pleased to present, gathered in these proceedings, the papers presented in the conference, which were stringently refereed and carefully selected by a Program Committee of 44 internationally renowned researchers together with the help of 12 external expert reviewers. We would like to thank the members of the Program Committee, the external reviewers, and the authors for shaping this conference.

We are very grateful to the scientific committee members for their dedication to improving the scientific quality and research value of ICOST 2009. We would also like to thank the Publicity Chairs, Industry Liaison Chairs, and the Local Organizing Committee for the successful organization of an internationally reputable event. We are very grateful that all these people and others behind the scenes accepted to put their international academic and professional experience as well as their reputation of excellence at the service of the success of this international event. We hope that we succeeded in disseminating new ideas and results that stem from the presentations and discussions.

July 2009

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Computer-Based Assessment of Bradykinesia, Akinesia and Rigidity in Parkinson's Disease

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Abstract. An increasingly aging population fuels the need for appropriate care and services for the elderly and disabled. Age related diseases such as Parkinson's Disease (PD), require close monitoring and assessment. A home-based assessment tool, which collects information on people's hand and finger movements, has been developed. It is intended that movement difficulties such as bradykinesia and rigidity can be identified through the use of this tool. Remote monitoring of this home based tool has the potential to decrease the number of clinic/hospital visits a person with PD requires. Two groups of 10 people took part in an evaluation of this system. One group were persons with PD and the other were without PD. Results showed that 70% of the control group completed the tool within 30 seconds compared to only 30% in the PD group. The tool endeavours to make the assessment of PD more objective.

Keywords: Parkinson's Disease, Assistive Technology, PD Assessment, Bradykinesia/Akinesia, Healthcare Technology, Rigidity.

1 Introduction

People are living longer, resulting in an increasingly aging population. European figures suggest that the "number of people aged 65 to 80 is expected to rise by nearly 40% between 2010 and 2030" [1]. With age often comes age related diseases such as Alzheimer's and Parkinson's disease. This demands an increase in the care and services being provided for both the elderly and disabled. As the challenge to ensure that there is adequate care available for the elderly and disabled increases, the use of Assistive Technology (AT) is being explored as one option to meet this challenge. An AT is a device which can enable a person to undertake a task independently which otherwise they would be unable to do without assistance from a carer [2]. Currently one of the most effective ways in which to care for the elderly/disabled is through an institutionalised form of care delivery. The reason for this is largely due to the level of care available in various institutions resulting in each person being able to be monitored closely. As such AT is beginning to be used in such a way that it can both assist the

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user with various tasks in addition to being able to monitor them. The net effect of deploying such technology inevitably means that elderly and disabled people can live at home for longer, safe in the knowledge that their wellbeing is still being closely monitored. Alternatives to institutionalisation have been proposed in the form of the ‘smart home’. A ‘smart home’ can be viewed as an environment which has been designed to enable independent living through provision of technical support to the person living there [3]. It also has the potential to monitor the person living within the home in order to ensure their safety and also to detect changes in behaviour and activity patterns over a given period of time. The aim of this paper is to present and evaluate a prototype home-based assessment tool which can help detect features of PD such as, bradykinesia, akinesia and rigidity.

2 Parkinson’s Disease

It is estimated that, worldwide, four million people have developed PD. In the UK alone, one in every 500 people will develop the disease [4]. The risk of developing PD increases with age as features begin to become apparent after the age of 50 [5]. Anyone who does develop the disease at 40 or younger is said to have ‘young-onset’ PD. The part of the brain affected by PD is known as the ‘substantia nigra’. This region of the brain is in control of movement and when PD is present, it experiences a lack of dopamine (neuro-transmitter). With the correct level of monitoring and care provision people who develop PD can maintain a high quality of life for as long as possible. Due to the wide range of features that are associated with PD, it is sometimes difficult to diagnose easily. Each person who experiences PD can exhibit an entirely different set of features. The four main features of PD are all movement (motor) related. Most people with PD will have at least one of the four main features (Table 1 [6]). There are many other common features which are often observed in PD, including; cognitive problems, dribbling, depression and dementia. Although these features may not seem as debilitating as the four main features, they can all impact upon everyday life.

Table 1. Details of the four main features of PD

Feature	Description
Tremor	An uncontrollable movement which has a rhythm (normally 4-6Hz). The form of tremor observed in PD is known as ‘resting tremor’.
Rigidity	A stiffness in multiple parts of the body which can often lead to a complete lack of movement at it’s most severe. Can make tasks which involve a change in position very difficult to carry out.
Bradykinesia/Akinesia	Difficulty in initiating movement and sustaining the movement. Akinesia is when attempted movements become frozen.
Problems with walking & posture	Stability during the walking process decreases and falls begin to occur. Often the posture becomes stooped, leaving walking more difficult.

Diagnosis and assessment of PD is currently carried out by asking the person to perform a number of subjective tests/tasks. These tasks include finger tapping and nose touching whereby people are asked to continuously touch their nose or tap their thumb with their finger. The clinician observes as each task is performed and then makes a judgement on the level of tremor, for example, that a person is experiencing. They are assisted in making their decision by the Unified Parkinson's Disease Rating Scale (UPDRS) [7], which contains several sections relating to various features associated with PD. Diagnoses and assessment currently takes place in a clinic or hospital environment, resulting in a high number of hospital visits for people with PD. Aside from the assessments that take place for diagnosis purposes, it is also necessary to closely monitor how a person with PD reacts to various medications. There is no one medication used to treat PD. Each person is recommended a medication and tries different drugs until they find one most suitable for them [6]. This is why close monitoring is essential, any negative reaction to a certain medication can be identified quickly and the medication changed.

The assessment tool developed within the current study aims to assist with the diagnoses and monitoring of PD through the use of a computer-based task. Through the use of this tool the decisions made in relation to the assessment of PD could become more objective. Hand and finger movements are collected by this tool in an attempt to highlight any slowness, bradykinesia/akinesia or rigidity that may be present in the user. Although this tool has the potential to show the presence of some other features of PD such as tremor and dyskinesia, we will only focus on bradykinesia/akinesia and rigidity within this paper. The anticipated long term benefit of the tool is to reduce the number of hospital visits needed whilst providing an unobtrusive manner within which tremors may be recorded. This decrease in the number of hospital visits could be achieved by a patient completing this remote form of monitoring/assessment in their own home, and therefore increasing their sense of empowerment and possibly their quality of life.

3 Relevant Work in the Area

Currently there are a large number of research projects being undertaken which endeavour to both automatically assess/diagnose PD and enable a more independent home life [8], [9]. Most of these proposed solutions process information collected from accelerometers and body worn sensors to assess bradykinesia/akinesia or rigidity. An example of such research is a system designed to quantify bradykinesia and tremor in PD as presented in [8]. In order to collect the movements made in the wrist and arm a 3D sensor was used. Each of the ten participants who took part in this bradykinesia and tremor quantification study were asked to carry out everyday tasks whilst wearing the sensor. The results showed that there was a clear difference in the measurements collected from the control and PD groups. Although the results from this study were positive it did involve the use of invasive technology.

As previously discussed, the finger tapping test is one of the key methods of assessment used for PD. The aim of this test is to show coordination, speed and accuracy. A more objective way in which to carry out the finger tapping task has been proposed, whereby sensors are placed on the finger and thumb [9]. A three axis accelerometer is placed on the joint between the finger and thumb in order to collect a more accurate reading. The participants in the study were asked to tap their thumb with their finger in the same way they would with the standard finger tapping test. The results of this test were compared with the criteria for the finger tapping test on the UPDRS and a correlation could be seen. Similarly to the bradykinesia based study discussed earlier, this proposed solution could assist with enabling home monitoring of people with PD. It is, however, slightly invasive due to the need for various sensors and an accelerometer to be placed on the user's hand.

The proposed solutions discussed are only an example of the ever expanding research that is being focused on enabling people to live at home longer by creating a form of remote monitoring [10]. To further improve the ubiquitous nature of these solutions and their impact solutions which are more embedded in the home environment and less obtrusive to the user would be very much welcomed.

4 Methods

This prototype is intended as an additional tool to be availed of during the assessment process rather than as a replacement to the current techniques used. Although on a small scale, this tool could assist with furthering the move towards utilising technology within healthcare. More specifically, this tool could be a form of monitoring for PD within the home environment and could compliment the UPDRS with regards to assessment. This aim could be realised through encouraging clinicians to use this tool when assessing their PD patients. If the tool was used on a regular basis, comparison of the results could be made to identify any deterioration or otherwise. With further modification this tool could be used in a more ubiquitous manner, whereby it runs in the background whilst a computer user carries out the standard computer tasks.

The current work aims to assess the potential benefit of using a computer-based assessment tool to identify the presence and level of bradykinesia/akinesia and rigidity which may be directed towards home based use. Visual Basic .NET was used to create an assessment tool which only relied upon the use of a computer and a standard computer mouse. The tool required that each participant moved the mouse pointer towards an icon on screen, and clicked on it, repeating this process for every icon (see Figure 1).

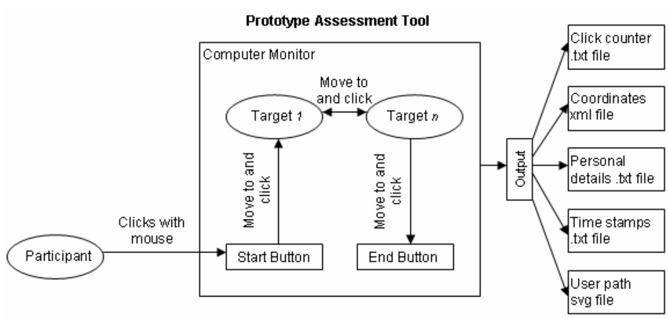

Fig. 1. A process diagram for the prototype assessment tool

Based on the movements made by the participants various pieces of information can be collected such as the speed of movement (pixels per seconds), the location of where clicks took place (x,y coordinates), and how long they took to complete the tool (seconds). Currently, analyses of the data is carried out by semi-automated calculations.

A group of 10 people between the ages of 40 and 90 who had been diagnosed with PD were recruited to take part in this evaluation. A control group of 10 people between the ages of 20 and 90, who did not experience PD, were also asked to participate (refer to Table 2). As age is often a delicate matter, the participants were only asked to indicate the age range they fell into rather than an actual age.

Table 2. Details of the participants and criteria used during the enlisting of subjects

	PD1	PD2	PD3	PD4	PD5	PD6	PD7	PD8	PD9	PD10
Age	41-50	41-50	61-70	51-60	51-60	71-80	41-50	81-90	51-60	51-60
Gender	M	F	F	M	M	M	M	F	F	M
Computer level	High	High	High	High	High	Low	Low	Low	Low	Low
Condition	Mild	Mild	Med	Mild	Mild	Severe	Med	Severe	Severe	Med
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Age	31-40	21-30	21-30	21-30	31-40	51-60	81-90	51-60	31-40	51-60
Gender	M	F	F	M	M	M	F	F	M	M
Computer level	High	High	High	High	High	Low	Low	Low	Low	Low
Condition	None	None	None	None	None	None	None	None	None	None

All of the participants who took part in this trial were selected from either the City Way PD drop-in clinic in Belfast or the Movement Clinic in the Belfast City Hospital. The trial itself was conducted within the bounds of the ethical approval given (ref no. 08/NIR01/25) by the Office for Research Ethics Committees Northern Ireland (ORECNI). Each of the participants were invited to complete the tool in a standard working environment. The same laptop and standard computer mouse were used for each person completing the tool to ensure consistency. Five output files were created containing information such as time taken, distance travelled, location of each mouse click and the path taken. In order to determine the presence of bradykinesia or akinesia the primary feature worthy of consideration was time. One of the indicators of bradykinesia is difficulty in initiating and/or sustaining movement. With this tool any difficulty with initiating or sustaining movement can be determined by assessing the time taken by the participant before they click an icon. An icon appears in 10 different locations throughout the task in order to test both ease and speed of movements in various directions. In order for a more accurate comparison of the results, 5 of the people in both the control and PD groups were computer literate and 5 were not. The reason for this mix of people with various levels of computer ability was to ensure that any slowness or difficulties experienced simply due to lack of computer ability were identified and set apart from the PD related difficulties.

5 Results

The results collected suggest that a substantial amount of information on certain features of PD can be determined from this data. Tables 3 and 4 show the median time taken to complete the tool by each participant in both the PD and control groups respectively. They also highlight the range of times taken by each participant to click each icon. Participants 1 to 5 in both tables represent those who were computer literate, with participants 6 to 10 being non-computer literate. The results presented in Table 3 show that 5 of the 10 PD participants have a significantly slower median time and these results come from those in the group who were not computer literate. The range of time taken is substantially larger in the same 5 non-computer literate participants in the PD group. Those participants in the PD group who were computer literate have a lower median time and range, as would be expected.

Table 3. Detailing the upper and lower percentile range and median time taken (in seconds) by the PD group participants to click each target

	PD1	PD2	PD3	PD4	PD5	PD6	PD7	PD8	PD9	PD10
Computer level	High	High	High	High	High	Low	Low	Low	Low	Low
Low	1.38	1.8	1.86	1.96	2.13	4.94	4.94	9.58	11.55	8.84
Median	1.66	2.95	1.95	2.31	2.34	6.61	6.91	14.14	15.78	14.78
Upper	2.34	6.08	2.81	3.24	2.45	16.33	10.97	43.48	41.98	20.27

Similarly, Table 4 highlights a difference in the median time taken by each participant in the control group who were more familiar with computers than those who were not. The difference in the median time of the literate and non-literate participants is less significant in the control group than in the PD group. Nevertheless, all of the median values for the control group are significantly lower than those of the PD group. The ranges witnessed in the control group are considerably lower than the PD group. A clear difference can still be viewed between the members of the control group who were computer literate and those who were not. The participants who were less familiar with computers have a larger range than the others. There is one exception to the rule, C5 was not familiar with computers, managed to have a similar range to one of the slower participants in the computer literate section of the group.

Table 4. Detailing the upper and lower percentile range and median time taken (in seconds) by the control group participants to click each target

	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10
Computer level	High	High	High	High	High	Low	Low	Low	Low	Low
Low	2.05	0.78	1.17	0.77	0.72	1.22	9.38	4.48	3.74	1.48
Median	2.34	0.92	1.31	0.84	0.8	1.27	13.69	4.77	4.83	1.69
Upper	2.47	1.23	1.55	1.41	1.46	3.73	21.59	7.2	5.13	2.19

6 Discussion

The results collected have proved many of our expectations to be true, such as, that people with PD would take longer to complete the tool in comparison to the control group. Within the results collected by this tool, evidence of the existence of bradykinesia, akinesia and rigidity can be identified, to a degree. An indication that rigidity is present could be determined by the slowness of movement around the screen and the position at which the icon is clicked. Generally, rigidity will make the time of each movement seem quite jerky and not well controlled. Akinesia could be represented in the results by a long period of time that passes without any movements being made. One of the key factors of akinesia is 'freezing' whereby the person cannot make any movements at all. In order to ensure that the long period of time without movement was caused by akinesia it is important to look at the speed taken throughout the remainder of the task, to determine if this period of stillness is in keeping with the person's normal pattern or not. Bradykinesia, in comparison is difficulty in initiating and/or sustaining movement rather than a complete lack of movement. Within the results this is highlighted through an abnormally long period of time passing between an icon appearing on screen and the person clicking on it. This delay may be a result of the difficulty in initiating movement.

A clear difference can be seen between Tables 3 and 4. The time related data for the PD group, displayed in Table 3, contains significantly higher values from those within the Control group. Each participant in the control group had a median value of 5 seconds or under, except for one. This one member of the control group, who had a median value of over 5 seconds, was the oldest at 89 years of age. Even with the age related effects that this control group participant obviously encountered, the value is still lower than most of the participants in the PD group. This could indicate that PD does impact upon the performance of people undertaking this task. The computer literate members of the control group fall into the 1-1.5 second median value range, whereas the computer literate people in the PD group fall into the 2-5 second median value range. We can see from this that even those who were familiar with computers in the PD group, experienced PD related difficulties which made their times slower. Tables 3 and 4 also clearly show that the upper and lower range of values for the computer literate participants in the control group are quite equal and each of the five have a very similar range. This shows the level of competency displayed by the computer literate section of the control group. In contrast those in the PD group who were not familiar with computers have a varying range of values. Some have a very large range and others slightly lower, however, still higher than the equivalent set of people in the control group. Within both the PD and control groups there is a participant who has had no computer experience at all and falls into the upper range of the 80-90 age group. This participant's results are displayed as number 4 and as number 7 in Table 4. We can see from this example that the upper range for the PD participant is just under 60 seconds which is significantly higher than the equivalent participant in the control group. This further highlights the difference that PD can make on the effectiveness to complete the tool.

After careful consideration and analysis of the results of this assessment tool, it is clear that it has the potential to become a useful aid to clinicians for assessment and diagnoses of PD. Upon completion of this evaluation it was found that the results gathered had the potential to indicate the presence of other features of PD. These features include tremor and dyskinesia. By examining the exact path taken by the user

** Light grey = Control group 1   * Dark grey = PD group 1*

Fig. 2. Image showing the path taken by a PD group participant and a control group participant, between the start button and the first icon

and observing any unnatural movements in this path, combined with time, tremor and dyskinesia could be determined (see Figure 2).

It is anticipated that further work will include automating the analyses process of the results collected from this tool along with correlation of movements with various ADLs, for example, medication intake.

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An Assistive Computerized System for Children with Intellectual and Learning Disabilities

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Abstract. This work proposes an assistive computerized system using the Arabic language for children with intellectual and learning disabilities (ILD) who are resident at Shafallah Center in Doha, Qatar. The system is flexible and can be used by parents, children and teachers, where they can employ the materials according to specific needs. The contents are developed with the help of special education instructors. The tutorials cover a range of topics on basic concepts of living including simple mathematics and sciences. The animated images used in the tutorials are taken from the children's environment, so they can feel more comfortable when using the system. After studying the tutorials, children can solve puzzles based on the topics they learned. A simple intelligent greedy algorithm is used to guide children to a solution. Concept analysis are used to extract the main ideas of electronic texts and dialogues, link them with images, sounds and clips, and present them to the children with ILD.

Keywords: Multimedia Tutorials, Intellectual Disabilities, Special Education.

1 Introduction

The number of people with disabilities is growing dramatically. *Sik Lányi et al.* mentioned in [16] that around 10% of the world's population suffers from some kind of disability. In the USA, about 14% of the population suffers from disabilities [14]. According to forecasts, in Europe, at least 18% of the population will be disabled during the next 20 years. The present population of Europe is around 450 million. This means that more than 81 million people will suffer from some kind of disability by 2040. Unfortunately, there is limited statistical information about people with disabilities in the Arab countries. A recent study conducted by *Al Gain* [1], estimates that 3.73% of Saudis have functional disabilities. A recent study conducted in Jordan shows that the number of handicapped people is 63 thousands where 18% are with ILD. The data released by the Qatar Statistics center (2007) showed that the number of registered persons with handicaps is 5,378, comprised of 3,285 males and 2,120 females. The *Shafallah Center* has a total of 454 children. A total of 638 disabled

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people are registered with *Rumailah Hospital*. The *Acoustics Education School has a total of 102 patients*; the *Al Noor Institute* (262); the *Qatar Institute for Speech and Hearing* (34); the *Qatar Society for Rehabilitation of Special Needs* (3,694); the *Qatar Social and Cultural Center for Deaf* (144), and the *Qatar Social and Cultural Center for Blind* (50). A total of 1,556 patients are registered as mentally-ill; 1,110 suffer from different degrees of paralysis; 51 deaf and cognitively impaired; 632 as deaf; 358 as blind and 1,663 in the 'others.' Most of the people that figured in the total of 5,378 fell in the age group of 25 and above (1,875). The rest of the breakdown by age is: 20-24years (621), 15-19years (818), 10-14years (790), 5-9years (693) and less than 5years (581). Note that thousands of moderately disabled people living in the country are still undeclared. A recent census process is being conducted in the country. It aims at encouraging families whose children are with disability to declare them in order to get the necessary support. Extensive research has been carried out since 1995 to develop assistive tools for intellectually disabled children. *Mechling* [13] has conducted an extensive literature survey on research (1990-2005) on assistive technology as a self-management tool for prompting children with intellectual disabilities to initiate and complete daily tasks. She mentioned that, "although *Kimball*, et *al.* (2003;2004) outline instructions on how to create computer-based activity schedules with photographs and video models using *PowerPoint*, to date no research base exists to support this new and creative use of high tech systems in providing children with visual, auditory, and animated cues for following and transitioning between activities or use in other forms of self-management". We mention also, many prominent persons have suffered from reported intellectual disabilities, including *Albert Einstein*, *Thomas Edison*, General *George Patton* and *Whoopi Goldberg*. This project proposes an assistive computerized system that can enhance the capabilities of children with cognitive and developmental disabilities to learn basic concepts and communicate more effectively with others. We can then improve their self-reliance and independence as suggested in [2].

2 Background

Research to develop assistive tools for children with special needs is at the rudimentary level in the Arab world. *Al-Salman et al.* [3] have developed a prototype of Arabic Braille system for blind people. They have also launched a new project to develop Arabic Sign Language educational tools. Another research project to use modern techniques in teaching children with Dyslexia is being carried out in the *Prince Salman Research Center for Disability* [15]. *Jemni and Elghoul* presented in [10] a web based tool called *WebSign* that translates text to sign language. This tool needs to be validated by the hearing impaired community. *ALfakheer* from King Saud University has recently developed an educational web-based tool entitled *FAHEEM* for children with autism, whose performance has not yet been validated. Special needs instructors have individually developed Arabic tutorials for children with ILD using *Power Point* with low quality images [13]. The European Commission supports the pan-European project [4], which involves several partners across Europe. The project recognizes the important role of play in child development as a crucial vehicle for learning about the physical and social environment. It targets children who are prevented from playing, and is investigating how robotic toys can empower children with disabilities to discover the range of play styles from solitary to social and cooperative play. This family of robots has been used in the *Aurora* project [6], which investigates the possible use of robotic systems as educational tools to encourage social interaction skills in children with Autism. The Spanish project *AmIVital* [5] creates intelligent communication tools and devices for elderly and disabled people. The total allocated fund exceeds 20 million Euros. *Scott* [18] launched the Archimedes project that promises accessible technology for the disabled. *Chelin et al.* [7] propose a system that uses natural language to assist visually handicapped write compositions. *Dunlop et al.* [8] propose a digital library of frequent conversational expressions to help profoundly disabled people communicate more effectively. *Sik Lányi et al.* [16] spent 10 years writing more than 30 programs for people with disabilities in Hungary. They propose some entertainment programs for children with disabilities that respect their language, culture and tradition. The *LifeShare* project [12] aims to better the lives of children with disabilities through the use of ICT.

3 Curriculum for Children with Disability

The current curricula used at Shafallah Center are divided into three main categories: (1) *Pre-Academic*, (2) *Academic* and (3) *Post-Academic and professional qualification*. These curricula cover a wide variety of topics including: body movement and control, object and pattern recognition, speech expression and control, memorization and information retrieval, self-confidence, clothing, cleaning, toiletry, possession, playing, social relationships, transportation means, animals and plants, foods, use of tools, safety, time and date notions, travel and circulation, entertainment, sports, quantities and qualities, counting, measures, relations, images and symbols, communication means, simple reading and writing, music and songs, and sports. The instructors are currently using traditional ways of teaching. These instructors face a major problem transmitting knowledge. They have to maintain the focus of the children, repeat the same lesson many times and re-ask or restate the same questions. An assistive computerized system will significantly help these instructors more effectively deliver the lessons.

4 The System Features

The current main features of our system can be summarized as follows:

1. It proposes Arabic tutorials for children with ILD on different topics related to basic concepts and according to the curriculum.
2. It assists children with ILD write simple Arabic sentences correctly by offering a list of items (i.e. images and photos) and words to select from.
3. It allows Arabic word prediction and abbreviation expansion. Whenever the children begin to type a word, the system will display a list of frequently used words that begin with those letters. The children can then select the appropriate word from the display.

The following figure shows the images used in the daily activity tutorial from getting up in the morning till going to bed at night. The children can click on any image and get some explanation (i.e., text, sounds and clips).

5 Puzzles and Greedy Algorithms

After learning a specific concept like for instance the school day, children are asked to solve some puzzles with different levels of difficulty. These puzzles include assembling parts of pictures and images, ordering tasks to be performed during a specific activity, matching images, assigning the corresponding images to text and vice versa, listening to a dialogue or specific audio sentence and then selecting the right image and text. The puzzles images-based are seen as optimization problems and we solve them by using a local greedy algorithm which guides the children in each move to finally converge to the solution. At each move children perform, they are alerted through sounds and an animated mascot that either encourages them to go forward or change their move. An *optimization problem* is formulated as follows: *Minimize f(x) subject to x in D*. We call *f* the objective function, *D* the feasible region that satisfies all the given constraints, and a solution *x* in *D* a feasible solution. The algorithm starts from an initial solution *x*, generated randomly and repeat replacing it with a better solution *x'* (i.e., *f(x')<f(x)*) in its neighborhood *N(x)* until no better solution is found in *N(x)*, where *N(x)* is a set of solutions obtainable from *x* by slight perturbations. The proposed algorithms can summarized as follows:

```
LocalGreedySearch()
Begin
  x = Initial Solution
 Repeat
  x'= SelectSolution(N(x))
  If (f(x') < f(x)) Then x = x
 Until Stopping Criterion met
 Return x
End
```

```
LocalGreedySearchwithTabuList()
Begin
  x = Initial Solution
 Repeat
  x'= N(x) not in the TabuList
  If (f(x') < f(x)) Then x = x'
  Update the TabuList
 Until Stopping Criterion met
Return x
```

The algorithms randomly generate the puzzle parts (i.e., *x*) and calculate then the value of *f(x)* that represents the number of conflicts between the puzzle parts. The higher the value of *f*, the more distant the solution is. Children then try to rearrange the parts of the puzzle by moving them one at a time. They are then prompted at each move they perform. Whenever the value of *f* decreases, the children will know they are advancing as expected. The following figure explains the idea.

Initial Solution Generated Randomly **Objective Function Value $f = 8$**

Picture5	Picture4	Picture6	Picture3	Picture2	Picture1

Child Makes a Move

Towards Solution **Objective Function Value $f = 6$**

Picture1	Picture4	Picture6	Picture3	Picture2	Picture5

Child Makes a Move

...

Solution Found **Objective Function Value $f = 0$**

Picture1	Picture2	Picture3	Picture4	Picture5	Picture6

After learning the daily morning activities, children try to solve the following puzzle.

Go to School	*Take Breakfast*	*Take the Bus*	*Wash Hands*	*Go to Toilettes*	*Get Up*

The children then make a move. For instance, children may put the *Get Up* activity at the first position. Thus, the value of f will be decreased and the children will be prompted accordingly, thereby receiving non-threatening input. Children will see a pictorial prompt encouraging them to continue according to the visual cue and feed-back. The prompts below are given in the imperative to provide simple orders for the children to follow. This is based on the following linguistic assumptions:

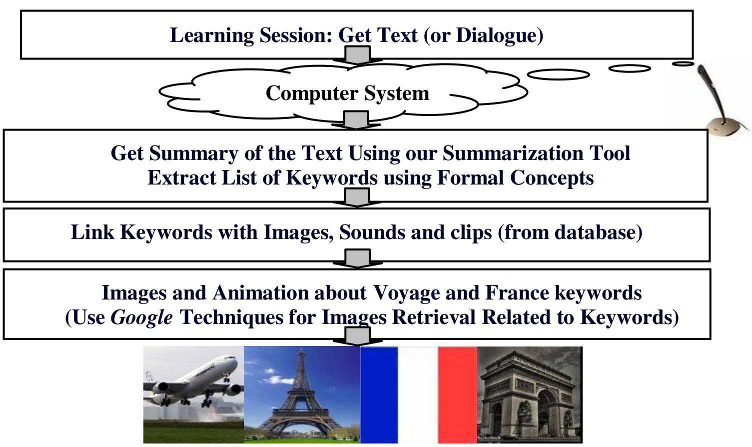
1. The imperative is a powerful linguistic tool to teach language.
2. Meaning can be conveyed through observational learning and imitation.
3. Memory is activated through learner responses.
4. Auditory, visual and kinesthetic stimuli better promote learning.
5. Corrections should be done in an unthreatening environment to preserve the self concept of children. Self correction should be promoted [11].

Get Up	*Go to School*	*Take Breakfast*	*Take the Bus*	*Wash Hands*	*Go to Toilettes*

If the children select, "*Take Breakfast*" in the first position, the value of f will be in-creased. Children are then prompted that they are going in the wrong direction. This process is repeated until children reach the solution. The system will then display the number of moves carried out and the time. A score is then provided to the children and stored in a personal file in the database. Student can then repeat the same puzzle with a different random pseudo-solution and self-test and evaluate. The following figures show a simple puzzle to be assembled by the children. It consists of grouping together the different parts of an apple. The mascot explains what to do in each step. It gives children encouragement when performing a right move. A progress bar is displayed below the puzzle. It indicates the work progress using red and green colors. To avoid reselecting the same move consecutively (i.e. recycling) a list of Tabu movements is used and updated at each iteration. The following figure shows the Apple puzzle along with the progress bar and the mascot.

6 Knowledge Extraction from Text and Dialogue

Feature extraction from text is known as keyword extraction, ontology, and semantic network. We use formal concepts (*FCs*) to extract the main ideas from electronic texts and present them to the children with intellectual disabilities. *FCs* have been introduced by *WILLE* in 1982 [19] and were applied in different areas of science. A strong feature of FC is its capability of producing graphical visualizations of the inherent structures among data. A concept is a maximal association between a subset of documents and a set of keywords indexing simultaneously these documents. Formally, it is a pair of two sets (A,B) such that the product AxB is included in the context (or binary relation relating a set of documents to associated indexing terms) is maximal. A lattice of concepts is an algebraic structure ordering the concepts from the more specific to the less specific. A formal context $k=(O,M,I)$ consists of two sets O (Objects) and M (Attributes) and a relation I as a subset of the product OxM. For two sets A and B such that $A \subseteq O$ and $B \subseteq M$, we defined two operators $f(A)=AR$ and $h(B)= BQ$ as follow: $f(A)=AR=\{m| \forall g\in A \Rightarrow (g,m) \in I\}$ $h(B) = BQ=\{g| \forall m\in B \Rightarrow (g,m) \in I\}$. Subset A is called the extent and B the intent of the concept (A,B). For each sentence, we create a row in the context relating the sentence to its indexing keywords. We may find different ways to represent a text with a context (i.e. a binary relation relating some specified parts of a text to associated keywords). A pseudo-concept is the union of all concepts $PS(s,w)$ containing a particular pair (s,w) belonging to the binary relation R of the context (O,M,R). For each pair (s,w), we define $PS(s,w)$ as the pre-restriction of R by the antecedents of w, and simultaneously its post-restriction by the images of s. The following graphic is a snapshot of one of our systems that extract the main ideas from an Arabic text using *FC*.



The images are retrieved from a specific database. Children can understand better the subject of discourse. They can click on any image and see a short clip and hear the corresponding explanation. For text to speech synthesis we are currently using the free *Euler* synthesizer from *MBROLA*.

7 Children Levels

The children in the *Shafallah* center have different degrees of intellectual disability, independent of their ages. These levels are as follows:

- *Level 1*: Children can understand one picture at a time with sound effect.
- *Level 2*: Children can understand one picture with sound effect and one word.
- *Level 3*: Children can understand some pictures and short sentences.
- *Level 4*: Children can understand pictures with sound effect and long sentences.

These levels are significant because they parallel first language acquisition. For example, *Level 1* is similar to the one word (holophrastic) stage children go through at between 9 months and 12 months of age. *Level 2* corresponds to the referential stage of language acquisition when children can name concrete objects and whose language generally consists of two words that convey meaning. *Levels 3* and *4* correspond to the expressive state of language acquisition when children experience extra linguistic input that encourages them to use multiple words to express more complex ideas. These children can understand pictures with sound effects and Arabic sentences with repetition (moderate case). Some of these children can surf the Internet and understand limited information. They will usually be reading and writing at a level noticeably behind that of their peers and may be reluctant to use the skills they do have.

8 A Case Study

We have selected 15 children from *Level 4* to use system. These children are able to use moderately the computer and understand simple Arabic text. Teachers and technical staff are assisting these children using the system. The first feedback of the teachers is very good. The system helped them to repeat the lesson several times and add some animation. Children feel happy with the puzzles which improved significantly their thinking and memorization skills. A deep analytical study is being conducted to evaluate the performance of the children using the system.

9 Conclusion and Future Work

We have developed the first prototype of the system that currently offers some tutorials on different topics for children of *Level4*. We have also designed the corresponding puzzles using multimedia and greedy algorithms to guide children with ILD toward the solution. Concepts analysis tools are used for main concepts extractions from texts and dialogues and present them to the children in different forms (images, clips and text).

***Future work*:** The future work will involve the completion of the following tasks: *(1)* complete the system features (words prediction to assist the children in writing, customize the database that the parents can add simple text and images); *(2)* conduct a deep analytical study on the selected children to evaluate their performance and progress; *(3)* Develop specific tutorials and puzzles for children of the other levels; *(4)* Develop a question answer tool for every tutorial.

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Design Challenges for Mobile Assistive Technologies Applied to People with Cognitive Impairments

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Abstract. Mobile devices can be used to provide assistance to people with cognitive impairments wherever they go and increase their independence. Due to the limited capacities of the target users and the constraints related to mobile devices, special care must be used when developing software. In this paper, guidelines are proposed to help in designing mobile assistive technologies for people suffering from cognitive disabilities. Examples of these guidelines application are given in the context of MOBUS: a system providing cognitive assistance and tele-monitoring of daily activities.

Keywords: Mobile Assistive Technologies, Design Guidelines, Cognitive Impairments.

1 Introduction

Mobile technologies have transformed the way people communicate, work and interact. Mobile devices are used every day in varied contexts such as buses, offices, and at home and offer greater independence for individuals who typically need to sit at a desk to accomplish various tasks.

When it comes to mobile devices, people suffering from disabilities, like any other mobile users, are continuously looking to improve their independence, keep in touch with their social network, and plan their activities. Mobile assistive technologies (MAT) help people with such disabilities: designers can take advantage of the mobility offered to develop applications that will help them achieve these objectives. More specifically, we explore how MAT help fulfill the goals of people with cognitive impairments (CI) due to diseases such as schizophrenia and Alzheimer or head traumas and cerebrovascular accidents.

The main advantage of MAT over desktop applications is that their mobility increases users' independence on their surroundings. For example, MAPS [1] helps people with CI complete daily activities by building scripts with images and verbal prompts that will guide them through the entire task. AbleLink Technologies [2] offer a wide selection of handheld solutions, from verbal and multimedia prompting to scheduling assistants.

MOBUS [3] supplies cognitive assistance and tele-monitoring to people with CI for their activities of daily living and includes tools to gather medical data. It consists of a mobile orthosis involving at least two Smartphones (one for the patient and one

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for each caregiver). It features activity recalls, symptoms notification, assistance request and contextual assistance. MOBUS has been designed with adults suffering from schizophrenia and other CI employing a user-centered approach. As this tool correctly answers many of the challenges presented in the field, it will be referenced throughout this article.

In this paper, we present the key challenges faced when designing MAT (which, in this document, refer to those aimed towards people with CI) and how guidelines that were previously established in the literature for AT can be adapted for mobility. Mobile devices are often small, do not use conventional inputs and are used in various contexts, whereas people suffering for CI may have reduced attention span, reading problems, etc. Separate solutions exist to the problem of designing for mobile applications [4, 5], and for people suffering from CI [6, 7], but no design guidelines exist for MAT.

As MAT offer great advantages over standard desktop assistive technologies, we find it important to combine the solutions mentioned previously and define actual challenges and guidelines specific to the field (see Table 1 for a summary). First we present the best ways to reduce cognitive load (load imposed on memory and attention) and deal with connectivity issues. Then, after every guideline presented in these sections, we discuss how MOBUS behaves in regards to these guidelines. We conclude by presenting experimentations that will be used to confirm the pertinence of our proposed guidelines.

2 Reduce Cognitive Load

One of the most important challenges when designing for individuals with CI is reducing the cognitive load imposed by the application. MAT users often present short-term memory and attention deficits, so they cannot sustain to put a significant cognitive effort in their activities. Since they are likely to use MAT in an urban environment (noisy and unpredictable), design is greatly influenced by the context [8, 9]. Therefore, designers need to ensure that the application only asks for the user's attention when necessary.

Device limitations (size, disk space, etc.) force decisions regarding cognitive load management that potentially represent costly consequences for people with CI. In this section, we expose guidelines to help reduce cognitive load in order to obtain an optimal MAT design. Each guideline is illustrated with examples from MOBUS.

2.1 Offer a Customized Experience

The first characteristic given by medical staff is the uniqueness of each person's CI [8]. In this case, the "Universe of One" theory, where a solution for one person will rarely work for another [10], is more than justified. Accordingly, customization is a critically important design requirement. A device adapted to the users' needs then reduces cognitive load by making decisions less time consuming. Furthermore, since users carry the devices everywhere they go and these mobile devices are, by definition, more personal than traditional ones [11], they tend to blend with a normal routine. Hence it is more likely that their user will want to personalize them and their

Table 1. Summary of MAT design guidelines for people with CI

	Objectives/Descriptions	*Features*
Customization	- Develop sense of belonging to the MAT *(M)* - Automatic adaptation to the specific needs of users *(M)(C)*	- Adapt to the context - Functionalities selection according to the user's needs and abilities
Feedback	- Reassure user about performed actions *(C)* - Give perceivable feedback depending on CI and context *(M)(C)* - Give consistent feedback *(M)(C)*	- Use audio, visual and haptic feedbacks - Give feedback after every action
Modalities	- Use various modalities to increase the chances of comprehension *(C)* - Adapt modalities to context *(M)* - Do not surcharge the interface or disk space *(M)(C)* - Use clear, concise and consistent messages *(M)(C)*	- Use visual, audio and haptic messages - Use images or sound when user cannot read easily - Use short and smart sentences - Use images judiciously
Error prevention	- Minimize situations that could generates errors *(C)* - Consider error possibilities due to smallness of screen and inputs *(M)* - Use consistent interfaces to facilitate use of the application *(M)(C)*	- Ask a confirmation before doing critical actions - Do a cognitive walkthrough adapted to the users
Inputs	- Use automatic inputs if possible *(C)* - Maintain minimum input possibilities *(M)(C)* - Keep input consistent, similar actions needs similar inputs *(M)(C)*	- Minimize cognitive load related to inputs - Use words choice instead of entire text input
Connectivity	- Manage variable connectivity *(M)* - Manage GPS reception *(M)*	- Offer constant assistance even in poor coverage areas - Offer alternatives when unable to connect to the network/GPS

(C): Important consideration for people with cognitive impairments
(M): Important consideration for mobile devices

applications to his/her preferences. Customization will lead the way to adaptive systems that can exhibit intelligent behaviour and possess the ability to support and co-operate with their users [12].

There are two categories of system adaptation [13]. The first one is offering users the capacity to select between different alternative presentation and interaction characteristics (GUI, colors, etc) among the ones built into the system. This will help MAT users develop a sense of belonging towards the application, as they have more control to adapt it to their preferences and personal limitations. The second one lets the application automatically identify circumstances that require adaptation and select an appropriate course of action by monitoring relevant types of data. As the application will be adapting to the user this monitoring helps decrease the load on their short-term memory.

Personalisation in MOBUS takes many forms. There are display customization options for the patient such as number of displayed activities, nature of the symptoms, and font size. Additionally, MOBUS proposes numerous functionalities people choose according to their needs. For instance, some people prefer to use the simplified agenda to organize their daily activities while others want to use contextual information in order to remember how to act in specific situations. Unfortunately, MOBUS customization requires significant computer knowledge. As the caregiver usually knows the patient best, he should be able to choose the customizations and change them himself, without having to bring the device to a specialist.

2.2 Give Regular System Feedback

People suffering from CI will sometimes feel overwhelmed by the use of a new application due to the high cognitive load it imposes. In order to diminish the feeling of not being in control of the application, the notion of feedback as given by Jakob Nielsen [14] should be enforced. Even when designing for traditional users, feedback is used to acknowledge their actions and keep them informed about what is going on. Considering the device restrictions that increase the risk of errors (e.g. small buttons and screens) and the users' CI, giving appropriate feedback is critical.

Tarasewich [4] describes how feedback should be included in a traditional application, and how every aspect of it should be carefully added when designing for people suffering from CI. Feedback, whether it is a beep when pressing a key or an error message for an invalid input use, should be substantial and readily understandable. It can take different forms (audio, visual, haptic) and the more senses it stimulates the better it is for MAT users. Designers should take advantage of these different forms in order to give feedback that is adapted to the context. For example, visual or audio feedback is less recommended in a crowded environment (bus) than haptic feedback (vibrations).

Additionally, it is important that the feedback stays consistent with the action that triggers it and the signification to which it is associated. When the same templates are reused, it is easier for the user to understand and react accordingly.

MOBUS has been thoroughly tested by performing cognitive walkthroughs to ensure that the given feedback is adequate, so users always know what the consequences of their actions' are. To help reduce cognitive load, our proposed improvement is to use a variety of sounds, depending on the nature of the alert (e.g. one sound for a late activity, another sound for a new one, etc.) so the user already knows before looking at his screen the type of the current alert, and can react accordingly. Another improvement that could be done is the use of haptic feedback. Audio and visual feedbacks are given by MOBUS to remind the user of his activities, but it is not convenient in noisy public environments.

2.3 Modality of the Message

When developing MAT, characterized by limited disk space and screen size, designers often wonder what the best way to communicate information is. For example, is replacing words by images a valid strategy? When using only images, designers have to deal with restrictions such as people's vision, cognitive processing, and cultural references.

To solve this problem, Lewis presents the option of multimodal messages, such as text and image, or text and sound [6]. But with the limited disk space, designers cannot always stock audio sentences on the device; with their small screen size, they may not have enough space for images and text. Messages may translate inadequately into images, which forces designers to rely exclusively on text and deal with the large proportion of people with CI that cannot easily read. Hence it is essential to put a significant amount of time in knowing the exact strengths of MAT potential users and to maximize their comprehension by using the best suited modalities.

MOBUS uses multiples modalities to communicate its message. For example, the colors orange, green and red are used to qualify the state of the planned activities. This way, just a glance at the screen allows the patient to know which activity he was supposed to do before, and which one he should do in the future. Another example is audio cues given when activities states are changing, or when a new activity is scheduled to begin. An improvement that we propose for MOBUS is the integration of images to accompany text on the screen. Images are not integrated in the current version of MOBUS, but would be helpful if the users suffer from severe CI. Finally, as previously noted, the absence of haptic feedback is an important limitation and MOBUS would greatly benefit from this additional modality.

2.4 Error Prevention

Designing a usable application for people with CI requires a great comprehension of the common errors each of these impairments is likely to cause. The use of mobile devices induces error-prone situations: input buttons are small and hard to interact with, small screens are hard to read or organize information into, etc. A careful design which prevents a problem from occurring in the first place is superior to good error messages. Designers should either eliminate error-prone conditions or check for them and ask users for confirmation. Another drawback comes from the size of the device: it forces the use of deep interfaces instead of broad ones, which forces to retain one's attention throughout the interaction [6]. People with CI, who often have reduced attention span, will therefore be more inclined to reproduce errors when using MAT.

The number of errors made by the users can also be decreased by having consistent interfaces as they reduce the application's cognitive load and learning curve. When using objects to represent actions or to display information, it is important that objects that act similarly look similar. Also, the meaning associated to specific colors and pictures as well as the general look and feel of each screen should stay consistent in order for the user to easily recognize the behaviour of the application.

To eliminate error-prone conditions with MAT, a good design adapted to the need of the patients is crucial. The THEA process [15] can be easily adopted for MAT. In this process, designers can understand how errors arise by performing a questionnaire-based error analysis. It also gives designers the ability to anticipate areas of potential interaction failures of the system. This questionnaire, or any form of cognitive walkthrough that can be adapted for people with CI, could also be completed, not only by designers, but by caregivers or patients who are aware of their own limits.

As stated before, one way to prevent the interfaces from being overloaded with information is to design them as deep instead of broad. This approach has been used by MOBUS. To diminish the error rate due to the high level of attention required, designers made sure to add frequent confirmation screens, and remind the users of their precedent choices. Unfortunately, the application is not consistent in the reminder of the actions done: sometimes, users are confronted to a screen with no reminder of their previous choice. This is problematic for users with a short attention span. Also, MOBUS would benefit from implementing an easy and consistent way to cancel actions.

2.5 Inputs

The small size of mobile devices implies the use of other input methods than the one generally offered by desktop computers. To avoid reducing the input possibilities, the designers have to find creative ways to allow the users to enter complex information such as text. This increases the difficulty of inputs and has a major impact when designing for people with CI.

To keep inputs as simple as possible, everything that can be automated should be. Also, the quantity of possible inputs should be limited to the minimum required. Gong and Tarasewich [11] gives an example of how to achieve these objectives when the user is asked to enter a word. Instead of requiring a text input, word selection among a small set of valid responses can be used. Keeping inputs consistent is crucial in order for them to become automatic responses for the desired user action, thus reducing cognitive load.

MOBUS has simple inputs that do not require text entry. The stylus is used to push buttons or select items in a list, and text and buttons size can be adjusted. However, users have expressed the need to extend MOBUS functionalities, for example by allowing them to manage their own schedule. More complex inputs may be required and designers will have to be careful to limit text entry as much as possible by presenting a list of objects, choices or images.

3 Connectivity Issues

The constraints imposed by mobile computing complicate the design of mobile information systems. Aside from the need for batteries and limited computational resources, there is the problem of variable connectivity levels [16]. Some buildings may offer reliable wireless connectivity while others may offer no connection at all. Outdoors, the same problem appears: gaps in coverage are frequent. MAT sometimes use GPS (Global Positioning System) technologies or data servers to help users orient themselves and monitor their activities. Those systems can suffer from connection problems if the user is inside a structure or outside the system's coverage area. When the connection fails, caregivers and patients can only depend on the last data received by the server (usually their last position outside). If MAT designers want their application to reach a maximum of users, they must manage the way it reacts whether it has access to a specific network or not. Patients and their helpers depend on these applications, often to communicate. If they cannot rely on the device, they will usually find the application useless.

In past MOBUS iterations, the connection to the server was vital: when it was unavailable, MOBUS was unusable. To solve this problem, mechanisms have been implemented in order for the mobile application to be able to work autonomously from the server for 12 hours. Currently, when connection is lost, MOBUS stocks user essential information (e.g. activities, symptoms) until connection is re-established. This is important for users and their caregivers so they can rely on the device. As for GPS data, MOBUS only stocks the last known position: future iterations should make a continuum between inside (without GPS position) and outside support.

4 Conclusion

In this paper we presented different guidelines that can be applied to mobile devices for people with CI, such as how to reduce cognitive load and manage connectivity, in order to help the designer when he lacks sufficient knowledge in cognitive sciences. We applied every guideline to MOBUS to evaluate its usability and issue recommendations to make it even more suited to the needs of people with CI.

To validate our work, we are currently designing a new system on a small watch-like computer, based on these guidelines, involving users with CI in a user-centered approach. With this project, we are currently receiving feedback from our users that will improve our research. We also intend to evaluate the next version of MOBUS by observing the benefits of the guidelines usage on the application's usability. Further work will focus on new design notions to propose guidelines not only for people with CI, but also to increase the usability from the caregivers' point of view.

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Mapping User Needs to Smartphone Services for Persons with Chronic Disease

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Abstract. Assistive technology is becoming increasingly prevalent within today's ageing society to help improve mobility, communication and learning capabilities for persons who have disabilities, chronic diseases and age related impairments. The effect of using such technology promotes a level of independence in addition to improving social awareness and interactions [1]. As trends in life expectancy increase, the number of age related impairments and chronic disease within the elderly population will also rise. While for some of these conditions there is no cure, with the help of assistive technology, diseases such as Alzheimer's for example may be effectively managed. Assistive technology within this domain can be used to support activities such as medication reminders, picture dialing phones and clocks to support day/night orientation. This paper presents an overview of the challenges associated with those suffering from chronic disease, in particular Alzheimer's disease and defines the methodology of how current advances in mobile phone technology and their associated services may be used to alleviate some of the issues experienced by chronic disease patients.

Keywords: Assistive technology, Alzheimer's disease (AD), Independent living, Mobile phone.

1 Introduction

Studies have shown that within today's ageing society the number of old and very old people is increasing along with the average life expectancy. Worldwide there are currently 650 million elderly people, and this figure is expected to reach 2 billion within the next 40 years [2]. Along with the increase in the number of elderly people, the average life expectancy has also increased from 55 years old in 1920, to over 80 years old today. Due to these figures demand on health and social services will therefore also rise [3].

Along with old age comes increased prevalence of age related impairments including both physical and cognitive challenges for example, older people are much more likely to develop vision impairments, hearing problems, memory loss, diminished motor responses, reduced mobility and long term chronic diseases [4] (a disease of

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long duration and generally slow progression[1]). According to Zhang *et al.* [1], in 2006, Europe exhibited the highest proportion of the population aged over 65 with a figure of 16.8%. This percentage is expected to reach more than 28% by 2050, with an estimated group of 80 million people having chronic diseases that will need care and assistance.

Based on the above figures, which describe the growth in the elderly population, it seems apparent that efforts should be made to alleviate some of the problems associated with old age and chronic disease. A potential solution to this problem is the use of information and communication technology (ICT) in the form of a mobile phone. In recent years academics, researchers and industrialists have focused a growing interest on modern day technologies, in particular mobile phones, in order to monitor health and well being. Nevertheless, mobile phone manufacturers are targeting very general conditions such as blood pressure, heart rate monitoring and halitosis, conditions that off-the-shelf self test kits can already support. To-date no approaches or devices have been produced that fully realise the potential of modern mobile phones for wellness monitoring in the elderly.

2 Mobile Phone Technologies

In 2008 over fifty percent of the world's population owned a mobile phone [5], a figure which is likely to rise in years to come. Mobile phone handsets now provide the potential for explicit and implicit multimodal interactions using buttons, multi-touch screens, motion sensing and voice recognition. This alongside high degrees of connectivity supports mobile phones to capture, distribute, analyze and transfer large quantities of information securely across distances with great efficiency [6].

Current mobile phone handsets now also support a variety of software applications and offer a selection of technical functions, including voice and video calls, short messaging service (SMS), multimedia messaging service (MMS), and full internet access including email enabling easy and quick access to information and instant two way communications in real time twenty four hours a day, seven days a week.

It is therefore proposed that, by considering the opportunities provided by this broadening of the modes of interaction, functionality and the connected nature of mobile phones, a more clinically valid approach to wellness phones could be investigated. An approach that could potentially offer a viable solution to some of the problems associated with the elderly popualtion and chronic disease. With current 3G mobile phone technology now supporting data rates up to 10 Mb/s and hence facilitating bandwidth intensive applications such as TV, full-motion video and full internet access the opportunities are endless.

Modern mobile phones are often refered to as smartphones. Smartphones are mobile phones offering highly advanced capabilites beyond that of a regular mobile phone, with functionality close to that offered by a personal computer. Mobile smartphones also execute full operating system software, while providing a standardised interface and platform enabling developers to create applications [7]. A major benefit of smartphones

[1] "Eldis", [Online] Available: http://www.eldis.org/go/topics/resource-guides/health/chronic-disease

is also their ability to connect and interact with other devices through wireless communications such as bluetooth, WiFi, infrared and NFC.

Smartphone handset features may typically include full internet access including email, a personal organizer, contact management, a large user friendly touch sceen interface, a mini qwerty keyboard, an accelerometer, a camera and video recorder, pre-installed GPS hardware and software, the ability to read and edit documents in a variety of formats and media software for music.

3 Methodology

In order to identify and alleviate some of the problems associated with chronic disease a problem solving approach for mapping user needs of those suffering from chronic disease with mobile phone technology is required. The output from this approach which has been conducted can be viewed in Table 1. Within the matrix there are four common chronic diseases, spanning both physical and cognitive domains. The symptoms patients may experience on a daily basis are presented which have subsequently been mapped to a potential solution to help effectively manage this illness along with the mobile phone application that may be viewed to help assist the solution.

Table 1. Problem solving approach of mapping both problems associated with chronic disease with Smartphone technology

Chronic Disease	Symptoms/Problems	Needs	Mobile Phone Application	Research Studies
Congestive Heart Failure (CHF)	• Tiredness • Lack of Energy/Fatigue • Swelling of ankles • Shortness of Breath • Nausea • Abdominal Pain	• Exercise • Weight Check • Monitor Vital Signs i.e. heart rate	• Step Counter (Pedometer) • Video Conferencing • Heart rate/ECG monitor • Exercise Diary	• In – Time Study • Cardio Concept PC – Based System
Stroke	• Trouble communicating • Paralysis of part of the body • Difficulty walking • Dizziness/Headaches • Loss of balance and coordination	• Communication through text message/email • Easy to use mobile phone interface • Monitor exercise	• Touch Screen • Accelerometer • SMS/MMS • Videoconferencing	• PAMM (A Personal Aid for Mobility and Monitoring) • The Smart Project
Alzheimer's Disease (AD)	• Memory Loss/Forgetfulness • Difficulty carrying out everyday tasks i.e. cooking dinner • Isolation • Disorientation • Unable to think clearly • Frustration • Misplacing items • Mood change	• Reminders • Directions • Socialising • Diary of medication taken • Relax • Tagging items • Activity Monitoring and Assistance	• SMS / MMS • Multimedia Message • GPS, Global Positioning System • Internet chat/email/phone • Video Conferencing • Calendar • Listen to Music	• Computer Interactive Reminiscence & Conversation • COGKNOW • KITE (Keeping in touch everyday) • DAISY (Dynamic Assistive Information System)
Parkinson's Disease (PD)	• Shaking • Stiffness of Muscles • Slowness of Movement • Difficulty with posture and balance	• Exercising • Easy to use mobile Phone interface with big buttons	• Touch Screen • SMS • Exercise Diary • Step Counter	• Steady Clicks • Interfaces for Assisted Living for People with PD

4 Target Group

Using the above methodology, the user needs of persons with Dementia was investigated further in order to provide a deeper insight into how these needs can be mapped onto mobile phone technology.

Dementia is a well known progressive, disabling, chronic disease affecting 5% of all persons above 65 and over 40% of people above 90 years old [8]. It is one of the most frequently occurring diseases later in life. Its prevalence is ahead of cancer, cardiovascular disease and stroke, yet funding for Dementia is significantly lower than the others [9].

Neil Hunt, chief executive of the Alzheimer's Society states: "With every second ticking by, dementia costs the UK £539. We need to invest in dementia services, research, support and training and use what money is being spent more effectively. Planning now will save lives and money in the future." [9]. A report published to the Alzheimer's Society in 2007 highlights that at least two-thirds of care home residents in the UK have Dementia and that the disease costs the UK alone over £17 billion per year [10]. The most common form of Dementia is Alzheimer's disease (AD).

Worldwide more than 26 million people have AD, a dementing disorder, characterised by cognitive and behavioural decline. It involves the damage and death of brain cells and the breakdown of their connections which impact on memory, thought and language [11]. The needs of people with AD will vary depending on which stage of the disease they are experiencing. These needs range from memory support in mild dementia to support in almost all aspects of daily functioning in severe cases of the disease [8]. Typical symptoms of AD include memory lapses, difficulty with abstract thinking, confusion and disorientation, a decline in judgment, language problems, personality changes and mood swings, depression, tiredness, aimless wandering and difficulty carrying out everyday tasks.

Throughout the progression of AD the affected patient is likely to have one or multiple carers to assist with everyday activities such as washing, cooking, shopping, dressing and taking medication. These carers can be both formal and informal carers ranging from family members to paid care assistants. Assistive technologies can therefore be used to alleviate carers burden and help patients remain independent for as long as possible within their own home. Past and present studies that utilize technology to support persons with mild/moderate stage AD range from solutions such as medication reminders/dispensers to more advanced solutions such as activity sensors, which help monitor the activity within the home of a patient in order to ensure patient safety [12].

While efforts have been made to help assist persons with AD, a full technological solution to help assist with the key unmet needs remains unmet. According to Lauriks *et al.* [8] the top unmet needs of dementia patients are (1) the need for general and personalized information; (2) the need for support with regard to symptoms of dementia; (3) the need for social contact and company; and (4) the need for health monitoring and perceived safety.

The use of ICT can be viewed as one potential solution to help met all of the above needs. For example, pictures taken using the camera function may be used in order to trigger memory, an example of similar research using digital media as a memory aid is a project called SenseCam: A Retrospective Memory Aid. This involves a sensor augmented wearable stills camera that enables patients to view activities previously carried out in order recall certain events [13]. Navigation may also be used to direct the patient when lost. Previous research carried out within this area using GPS to direct patients, has been demonstrated within the CogKnow Project [14]. Althought an older person may not be expected to use mobile phone functions directly, the features of the phone may still prove very benefitical in assisting daily activities, and are presented in Table 2.

Table 2. User needs of AD and mobile phone applications that may be used

User Needs of AD	***Mobile Phone Application***
Memory Aid	SMS/MMS/Voice Calls
Reminsince	Multimedia pictures/Videos/Music
Exercise Diary	Pedometer/Personal Diary
Directions/ Patient Locator	GPS (Global positioning System)
Medication Reminders	Voice Call/SMS/Alarm
Medication Diary	Calender
Relaxation Aid	Music/Video
Activity Monitoting	Accelerometer/GPS
Activity Assistance	Multimedia (Video/Audio)
Social Networking	Internet/Email/Chat
Personal Organiser	Calender Management

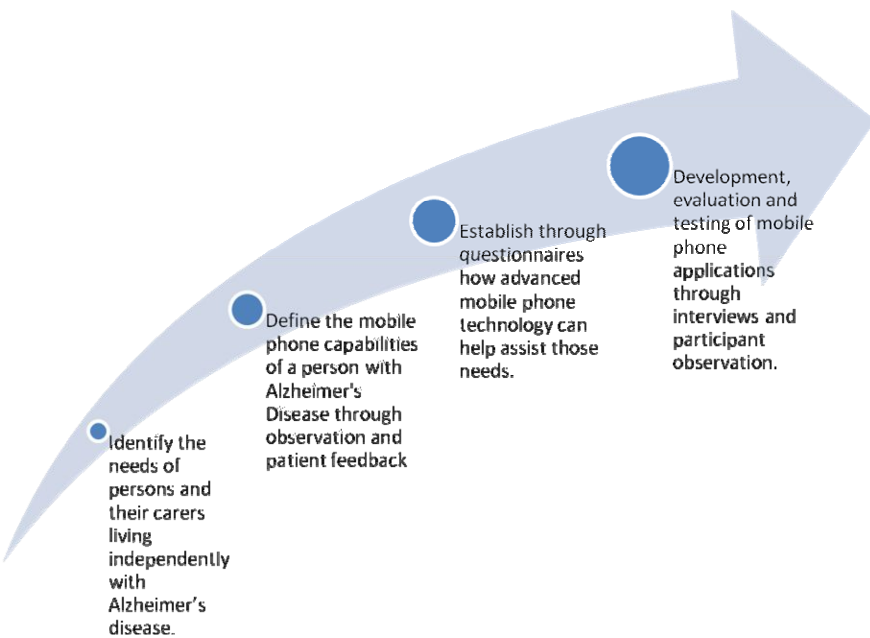

Fig. 1. Steps involved in achieving Project aim

5 Aim of Research

The key aim of this research is therefore to identify the needs of elderly persons living independently with mild Alzheimer's disease and to alleviate some of these problems using services deployed through mobile phone technology. The research will focus towards the best way to combine mobile phone technology functions with Alzheimer patient's needs for support. This in turn will allow the patient to remain living independently in their own home for as long as possible in addition to having the potential to alleviate carers burden. Steps in achieving this aim are presented in Figure 1.

6 Conclusions

With the population living longer, the increase in age related impairments and chronic diseases will also rise. As assistive technologies and services focus on allowing older people to remain at home independently for as long as possible, health services are changing drastically with the emphasis shifting from hospital to home and from treatment of chronic diseases to prevention and wellness. Thus health authorities are in search of a new generation of services to promote wellness, quality of life and quality of health services [15]. While chronic disease is non curable, by mapping both the user needs of chronic disease patients with mobile phone technology the needs of chronic disease patients may be effectively managed through the use of ICT, in particular AD patients.

Currently on the market today there are a variety of aids that aim to assist Alzheimer's patients on a daily basis, for example, wall clocks displaying the day, date and time, item locators, picture dialling phones and fall/flood/water temperature detectors. Nevertheless, to-date no approaches or devices have been produced that fully realise the potential of modern mobile phones for wellness monitoring in the elderly. Therefore to assist patients with AD, an approach using mobile smart phone technology could be adopted to promote the most effective and productive way forward.

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Trial Results of a Novel Cardiac Rhythm Management System Using Smart Phones and Wireless ECG Sensors

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Abstract. This paper discusses the trial results of a personalised Cardiac Rhythm Management (CRM) system using a smart phone (PDA) and a wireless ECG sensor. The system is used in a trial to record and diagnose abnormal cardiac arrhythmias. This novel approach uses standard mobile phones, off-the-shelf ECG sensors and personalised feedback to the patient when compared to a conventional clinical Holter and event monitor systems. The preliminary results are discussed of an ongoing trial conducted with the Royal North Shore Hospital in Sydney Australia. The results indicate the viability of the system for commercial purposes.

Keywords: Remote tele-monitoring, cardiac rhythm management, smart phones, wireless ECG sensors.

1 Introduction

Cardiac rhythm disorders impact millions of people each year. Some arrhythmias are difficult to diagnose because they occur sporadically in otherwise healthy adults and do not pose a threat to heart health. Other arrhythmias however, could indicate more serious, potentially life-threatening problems. Identifying and managing cardiac rhythm disorders is a field in cardiology called Cardiac Rhythm Management (CRM). It may involve the use of artificial pacemakers and/or implantable cardioverter-defibrillators as well as anti-arrhythmic drugs [1].

To capture relatively frequent arrhythmias a Holter monitor may be used. This is a portable device for continuously monitoring the electrical activity of the heart for 24 hours or more. A Holter monitor records the electrical signals from the heart via a series of electrodes attached to the chest. The number and position of electrodes varies by model, but most recording systems employ from three to eight electrodes [2].

To monitor patients with cardiac symptoms that only occur sporadically (e.g. once or twice a month) a cardiac event monitor can be used. Event monitors are activated only when the arrhythmia occurs or symptoms are felt. The advantage is that these recorders may be used for a longer period. This type of device only records cardiac events for typically 30-60 seconds. The recordings can then be transmitted via the telephone to ECG technicians for further processing.

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The Personal Health Monitor system developed by our team at the University of Technology, Sydney is a flexible CRM system that can be used either as a Holter monitor or an event monitor. The system is different from conventional Holter and Event monitor systems since it uses standard mobile phones and wireless ECG sensors. It is not limited to just recording ECG arrhythmias but offers a range of other functionalities, that make it a personal health monitoring system for people that need to make life style changes such as lose weight, lower the blood pressure or monitor their blood glucose level.

In this paper we focus on the use of the Personal Health Monitor system for CRM management which is being trialled by the Cardiology Department of the Royal North Shore Hospital in Sydney, Australia. The aims of the trial are to:

- Demonstrate that the detection of important cardiac arrhythmias is feasible using the Personal Health Monitor system utilising the Internet.
- Investigate whether the use of the Personal Health Monitor provides clinically meaningful reassurance to patients with suspected arrhythmias and heart disease.
- Obtain feedback from patients and cardiologists regarding usability and practicability of the software/hardware used.
- Obtain feedback on the usefulness/efficiency of *rehabilitation* in cardiac patients and elderly using the personal health monitor application.

The trial is an Observational Cohort Study. Two hundred patients with suspected or confirmed cardiac arrhythmias will be recruited over 2 years and technical, clinical and psychological experiences will be recorded. The value and significance of this research comes from assessing how easily available and economical non-proprietary technology for the detection of cardiac arrhythmias and vital signs will enhance clinical management via the internet. This will extend the applicability of present technologies especially for patients in remote locations.

This paper presents the preliminary results of the PHM trial with 70 patients. Section 2 presents an overview of the PHM system. Section 3 focuses on the remote assessment of arrhythmia data by the specialist. Section 4 discusses the trial results from both the patient's and cardiologist's viewpoint. Finally, section 5 concludes this paper.

2 Personal Health Monitor System

The Personal Health Monitor (PHM) provides personalised, intelligent, non-intrusive, real time health monitoring using wireless sensors and a mobile phone [3-5]. The wireless sensors can be either attached to the user's body (for example ECG and Accelerometer) or can be external devices, such as a blood pressure monitor or a weight scale, that are used when required. The sensors are Bluetooth enabled or integrated into the mobile phone. On the phone, the Personal Health Monitor software analyses, in real-time, the data received from the sensors. The phone gives immediate feedback and personalised advice to the user based on the analysis of sensor data collected.

The PHM offers the following functionalities which makes it attractive for cardiac rhythm management:

Ambulatory monitoring: Using small sensors and a mobile phone it allows convenient, non intrusive monitoring for a prolonged period of time, while users carry on

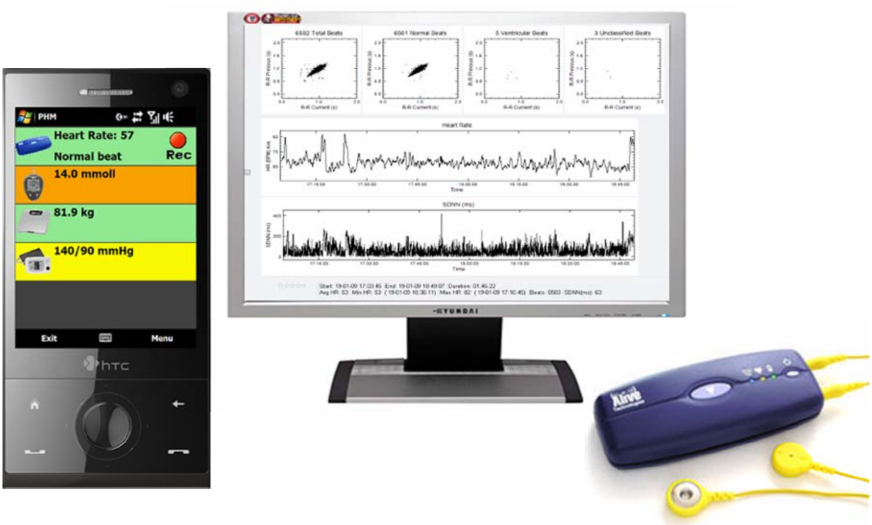

Fig. 1. Personal Health Monitor System

with their normal daily routines. The user needs a Microsoft Windows mobile phone, and may buy or rent the sensors. The user can download the software onto the mobile phone and use it just like any other windows mobile application.

Multiple sensors: The PHM system supports the following sensors: ECG, Fall detector, Pulse Oximeter, Blood Pressure, Weight and Blood Glucose. The PHM uses off-the-shelf sensors which are widely available on the market and their technology is mature. The advantage of off-the-shelf sensors is that health professionals trust these devices since they are FDA, TGA and/or CE, approved.

Instant feedback: The Personal Health Monitor analyses and stores biosignals and activity data on the phone and provides instant personal feedback to the user. If required, the phone can be set, in the event of a cardiac arrest, to loudly play a message with pre-set CPR instructions for any bystander, so that they know how to assist.

Personalisation: Each user has different needs and preferences and the PHM application can be configured to the patients' and health professionals' needs and requirements**.**

Arrhythmia detection: The PHM application can detect and record various arrhythmias and can react to serious arrhythmias such as ventricular fibrillation/tachycardia. The ECG signal quality (Fig. 2) is in the vast majority of cases of sufficient quality for a cardiologist to make an assessment.

Fig. 2. ECG trace from PHM system

Reminders and logs: The Personal Health Monitor software allows the users to set reminders for their measurements and to keep logs of their activities.

Communication: The sensor data and analysis can be instantaneously sent to the Health Care data server using 3G or any other Internet connection available on the phone. The PHM application can also be configured to provide alerts which automatically ring or SMS pre-assigned numbers in emergency situations, such as when it detects a life threatening arrhythmia or a fall. The PHM application can use either wireless or wired communication for synchronising data.

Remote configuration: The specialist can remotely configure the PHM application for each user by changing variables such as threshold levels for a particular sensor (e.g. max heart rate). In this way, the Personal Health Monitor software can be customised to the needs of each user or clinician.

3 Remote Assessment via Health Care Data Server

One of the strengths of the PHM system is remote monitoring and assessment of patients. The patient can upload the data instantaneously via 3G or any other Internet connection available on the phone to the www.PersonalHealthMonitor.net website. The health professional is notified of new data and can assess the results. Currently, the ECG assessment consists of heart rate variability (HRV) analysis and ECG traces. Additional information is shown such as the max/min and average heart rate, RR intervals, as well as, the arrhythmia symptoms detected for that ECG trace (e.g. ectopic beats). This allows the specialist to quickly assess the relevant traces. HRV time domain summaries are generated for the purpose of assessing autonomic regulatory effects on heart rate. The cardiologist can annotate ECG traces and HRV summaries which will then be added to a report specific for the patient.

4 Trials

This section presents the preliminary results of trails being conducted with the Royal North Shore Cardiology department in Sydney Australia. The trial runs over a period of 2 years (2008-2010) and aims to test it on 200 patients.

4.1 Process

The cardiologist screens potential subjects. Subjects with low risk cardiac conditions and suspected arrhythmias are recruited. Selected patients are instructed how to use the personal health monitor application and sensors. On average, 30 minutes are needed to instruct a patient, and a 5 page user guide is given for reference. The patients use the Personal Health Monitor when they wish to do so. Our recommendation is to wear it for one full day (usual Holter period) and when they feel symptoms. The patients keep the personal health monitor till they capture an event and most keep it for 2-4 weeks. For economical and practical reasons (e.g. 3G is expensive in Australia, not all patients have Internet connection), the data is uploaded to the website when the patient returns the equipment. The cardiologist examines the traces immediately in case the system has detected an important arrhythmia, or during the next appointment with the patient. The patient fills in the questionnaire after they return the equipment or after feedback from the cardiologist.

4.2 Preliminary Results From the Patient Surveys

At the time of writing, over 70 patients aged from 21 to 90 (Average age 56.6) have used the system and 47 patients (23 males, 24 females) have been surveyed about their experience with the PHM system. Our survey consists of 48 questions (a mix of open and closed questions). This paper focuses on 12 Likert-scale questions where the respondents indicate how closely their feelings match the question or statement on a rating scale.

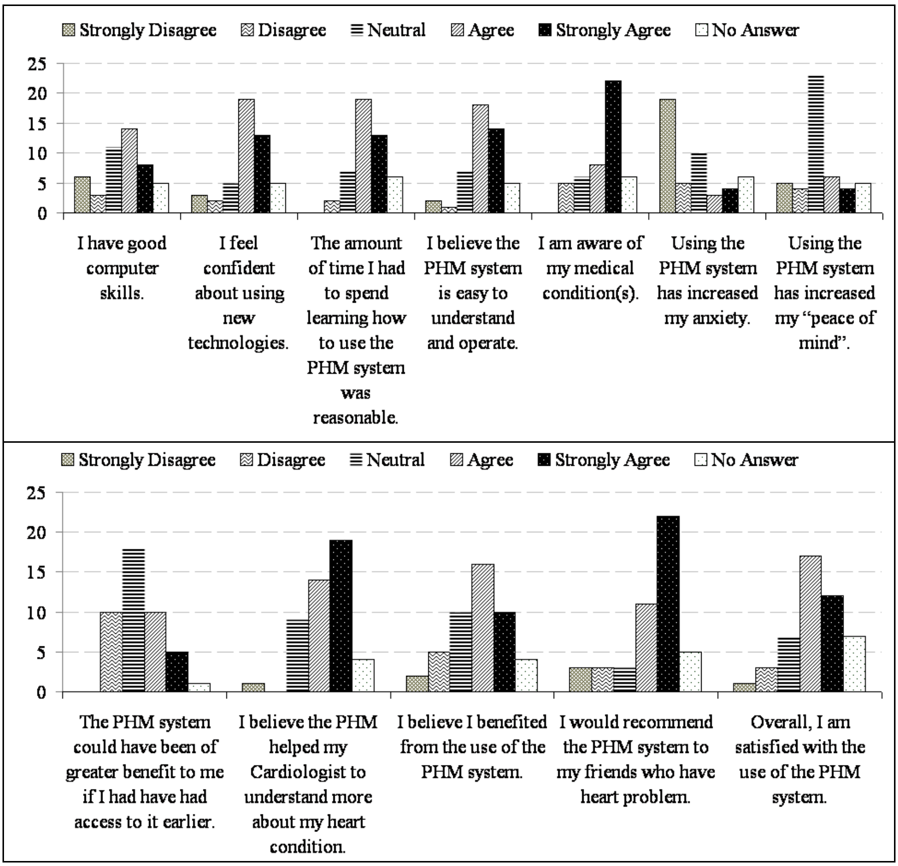

Fig. 5. Evaluation of the PHM system (y-axis = number of answers)

Most patients have reasonable computer skills and are confident about using new technologies. One of them, a 91 year old female has never used a mobile phone and despite this, she finds the PHM application easy to use and manages to record numerous ECG traces.

The vast majority of our patients find the PHM easy to use and consider the time spent learning how to use the PHM reasonable. Approximately 25% of the patients give a phone call a day or two after the first meeting to make sure they are doing the right thing and potential issues are clarified over the phone within a few minutes.

Most are aware of their health condition and wish to capture the arrhythmia and be able to show it to the cardiologist. The use of the PHM does not increase the anxiety for most patients. The few exceptions correspond to a feature in the PHM software that will play a loud voice message when the heart rate is too low or too high. This feature was added after one patient fainted due to a low heart rate. It seemed like a good idea at that time but it was quickly disabled since it led to more anxiety amongst other patients. The feature can now be enabled on specific request by the patient or cardiologist. The patients are neutral about the fact whether the PHM increases their peace of mind. For those at higher risk tend to agree that it brings piece of mind.

Most patients believe that the PHM helps their cardiologist understand their condition. Overall, they are satisfied with the use of the PHM and they benefit from it. They would recommend it to their friends that have a heart condition.

The survey contains several questions about the Holter monitor. 21 patients out of 47 surveyed used a Holter monitor previously and the vast majority find the PHM more convenient (89.3%) and easier to use (90.5%) compared to a Holter monitor. Only 54.6% find the PHM more comfortable than a Holter monitor which surprises us. A possible explanation can be that we use a fairly bulky phone (i-mate JasJam) and patients do not use this as their daily phone therefore carrying 2 mobile phones which might have an impact on the comfort. In the near future we migrate to a far slimmer mobile phone (HTC Diamond) which will hopefully improve the comfort level.

Several patients, especially women, develop some rash or skin irritation where the electrodes are placed and several find the ECG monitor slightly inconvenient. Some patients appreciate the online access to their ECG data, which improves their understanding of their heart condition. Some patient feedback:

"It had picked up Supra Ventricular Tachycardia (SVT) which I have had but never been able to capture it. I am now on medication and have had reduced symptoms and feel a lot more confident to be able to get back in shape and go forward".

"I think the monitor is an excellent diagnostic tool. As I informed you I have had the symptom for six years and more but have never been able to demonstrate it to any doctor, GP of specialist. Now with your assistance that has been done and that is very reassuring".

4.3 Cardiologist Experience

The PHM provides another tool for the efficient diagnosis and characterisation of heart arrhythmias, a very common disorder in clinical medicine. Previous clinical experience has confirmed the efficacy of ambulatory monitoring, but this smart phone based system will broaden the application of the technology to other conditions outside the realm of heart disease. Furthermore, careful selection of suitable patients will enhance the confidence of patients and acceptance of appropriate reassurance or treatment. The survey confirms the general satisfaction of patients with the system in assisting their diagnosis. It does not create undue anxiety.
Clear advantages of PHM include:

- Diagnosis of an unsuspected arrhythmia (e.g. heart standstill).
- Confirmation of a suspected arrhythmia (e.g. ectopic beats).

- Readily accessible low-cost technology which may be used as an adjunct to established monitoring systems.
- Option to remotely review tracings via the internet and website which is user friendly.
- Potential for linkage with other bio-markers (e.g. oxygen saturation, blood pressure and body position) using Bluetooth enabled systems.

Disadvantages include:

- The need to select patients who are not averse to using mobile phone technology.
- Tailoring of alert algorithms to avoid excessive anxiety in patients.
- Provision of surveillance manpower to skilfully screen traces and alerts (further automation may help).

The utility and feasibility of PHM has been demonstrated in the trial with individual cases such as:
Patient A who had suspect minor arrhythmias but the extent to which they occurred (atrial fibrillation) led him to be treated with anticoagulation to avoid strokes.

Fig. 6. Patient A - Atrial fibrillation with typical variable ventricular (heart) rate

Patient B who collapsed while wearing the device and was admitted to hospital with no abnormal findings. Review of the recordings which were forwarded to the treating Emergency Unit revealed periods of heart standstill for which he received a pacemaker. He has remained well since.

Fig. 7. Patient B: Junctional bradycardia with marked heart rate slowing corresponding to fainting symptoms

5 Conclusion

This paper presented a novel Cardiac Rhythm Management application using standard mobile phones and wireless ECG sensors which are Bluetooth enabled. To date, the application has been trailed on 70 low risk heart patients and the preliminary results show the commercial potential of this system for identifying and diagnosing arrhythmia abnormalities. The Personal Health Monitor system can be used as either a Holter and/or Event monitor but offers many more features which make it a multi purpose device for health monitoring. Areas where the PHM system has potential application are:

- **Cardiac Rehabilitation**: After a heart attack or a coronary bypass surgery the patient is involved in a personalised rehabilitation programme where the PHM application instructs and motivates patients to follow their exercise prescription and keeps track of their progress. It also monitors the relevant biosignals and provides immediate and comprehensive feedback to the patient and caregivers [7].
- **Community Healthcare**: Patients are remotely monitored by a home nursing or healthcare provider. Patients are given the PHM and additional equipment such as a weight scale, blood pressure monitor or glucose diabetes monitor and need to take their measurements according to a predefined schedule. The PHM will automatically remind the patient and once the data is collected it is automatically uploaded to the healthcare data centre for review by the staff.
- **Monitoring of Lifestyle changes**: For people that need to make lifestyle changes such as losing weight, fitness surveillance and blood pressure control. The PHM application can be used to monitor their progress without repeated visits to clinics or hospital departments.
- **Athletic performance**: Exercise enthusiasts and elite athletes may use the PHM application to monitor their sporting progress, or symptoms related to activity, particularly when exercising in remote areas.

We believe that the use of this system will be easily extended after further experience in real world situations measuring bio-data in selected groups of people. Because it employs mature technology the PHM system is unlikely to encounter limits on purely technical grounds. Its value in general community and clinical use will be further clarified by studies looking at cost effectiveness.

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Participatory Medicine: Leveraging Social Networks in Telehealth Solutions

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Abstract. Advancements in telehealth technologies offer health care providers and medical practitioners ever expanding solutions to improve the quality and timeliness of care. As the use of technology increases, corresponding attention needs to be given to bringing care providers closer to their patients. Extended networks of family, friends and healthcare professionals are integral to a successful care plan. Service oriented architectures and Web 2.0 technologies offer an effective approach to integrating telehealth solutions with social networks to create a new and innovative approach for offering patient centric care. These combined solutions offer the patient and the people who form their primary and extended care networks, a means to communicate, interact and adapt as needs and situations change. Enabling new and creative applications will improve the ability for medical professionals to deliver quality care by combining clinical data with a patient's own "network effect".

Keywords: Connected Health, Remote Monitoring and Intervention, Service Oriented Device Architectures, Social Network Applications in HealthCare, Smarter Planet.

1 Introduction

Networks of people are part of everyone's personal and professional lives. They take on special significance for the aging, disabled and chronically ill [2]. Care providers and their health plans become part of the individual's life. The professional care they provide is never in isolation. The network of care extends to family and friends, whose sharing, knowledge and involvement have a great impact on the individual's daily life and the effectiveness of the professional care provider.

Technologies like social networking and support forums are being utilized by the people around the individual, offering effective and meaningful interactions. These technologies are making it easier to share experiences and events across communities. Web 2.0 technologies enable individuals to produce and assemble content, and to interact in new and unique ways. For example, by using Blogs and Twitter, it is possible for anyone to author and publish an article, and let the world know what they are doing

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that instant. What's more, with Web 2.0 enabled sites like iGoogle, this information can be "mashed up" together using a technology called "gadgets", to form a user experience unique for that individual.

An important goal we all seek for our technologies and products is to bring care providers closer to their patients, to not only improve the quality of care but to personalize it. In this paper, we propose the integration of connected health technologies with social networking. This offers means to expand and evolve a patient's extended care network

2 Beyond the "Virtual Housecall", Illustrative Scenarios

As telehealth solutions become more prevalent today, they improve the quality of care by enabling the patient to take readings and measurements in the comfort of their home. In turn, this extended the reach of medical practitioners by providing the ability to make a “virtual housecall”, collecting all vital measurements remotely.

However, many telehealth systems are limited in that they provide only the ability to collect data. Social networking – a Web 2.0 technology - complements traditional telehealth systems by leveraging the social network of an individual, creating a “virtual extended care network” that enables a medical professional to see a more holistic view of their patients. In the following scenarios we demonstrate how the collective and trusted experience of an individual’s social network can be harnessed to extend and empower the concept of teleheath.

Web 2.0 offers a different user experience than typical “patient portals”. Rather than requiring the user to navigate to a specific site, healthcare providers can offer their content via a gadget. This allows the healthcare provider to deliver content directly to where the patient consumes it while still maintaining the integrity of the source.

2.1 Delivering Content via Gadgets

Charley, an aging independently senior, is managing his diabetes and related conditions through a tailored care plan along with the help of his telehealth clinician, Josie. Charley's blood glucose level, weight, blood pressure and activity information is automatically collected and sent to his care provider’s monitoring system, all configured according to a schedule and plan recommended by Charley's physician [8].

Josie monitors Charley’s collected data on a daily basis through her Web browser. Because Charley’s needs are constantly changing, for example, new devices are provided to his home, Josie frequently needs to add and remove different “views” of Charley’s data. Fortunately, this is an easy process because her “Patient Management” page is a collection of gadgets, each with a specialized visual representation of the information collected by the remote monitoring service. For example, when Charley received his blood pressure device, to begin viewing this data, Josie simply added the “Blood Pressure Readings” gadget to her “Patient Management” Web page. In addition, Josie is able to add other content that may be useful to the care of her patients directly to the same Web page, e.g. CDC [9] alerts for food and flu levels.

2.1.1 Leveraging and Integrating with Social Networks

A change in Charley's situation prompts his physician to enroll him in a drug trial program. One of the potential side effects of this new medication is a slowing of metabolism, making it more important for Charlie and Josie to watch is caloric intake. Charley is a member of a popular social networking site, and by browsing its available application, quickly discovers a "Meal Planner & Calorie Counter" application offered by a popular TV Food show. One of the main features of this application is that it will keep a two-week running total of Charley's calories and a diary of his meals.

As part of their participatory medicine strategy, Charley's healthcare provider has started a pilot program to integrate with popular social networking sites. Using programmatic interfaces provided by the social networks, Josie can view her patient's profile data, including their phone number, current address, e-mail and other information. Josie can retrieve her patient's social graph, including groups of friends. In this case, Charley has defined an "Emergency Contacts" group, in which he has identified which friends of his to notify if something should happen. In addition, Josie also has access into information provided by several of the applications Charley uses, e.g. the "Meal Planner & Calorie Counter". Josie is now able to monitor Charley's diet and discuss his meal choices and how it may impact his health.

2.1.2 Leveraging the Power of People

Charley's healthcare provider realizes that it is not possible for Josie to visit with all of her patients on a daily basis making it difficult for clinicians to get an overall sense of their patients' wellbeing.

However, they recognize that it is important for a patient to be able to tell their doctor or nurse how they feel. A patient's family and friends, especially those who are in close contact, also have valuable insight on their overall wellbeing. Charley's healthcare provider, in an effort to provide Josie with a more complete view of her patient's health, has registered a gadget with his social network provider. This gadget allows Charley, along with his "friends", to provide information about his mood, behavior, and their observations. For example, Charley's son, Adam, can add this gadget to his social networking home page, and from there, indicate that his dad is not feeling well, seems a bit nauseous, and is very lethargic. These readings are captured as input to Charley's health record, in the same way that information is captured from his telehealth devices. Josie sends a message to Charley via his social network, asking him to start using the "How do you feel?" application. Charley is now able to provide his own input into his medical record.

Because Charley is part of a social network, he has established a group of "friends" that are concerned about his progress through the drug trial. Charley shares this application with his friend network. When one of Charley's friends accepts his invitation to share the application, they are allowed to view how he is feeling as well as add their own observations. By sharing this application, Charley allows his social network to directly participate in his care. Because at least one of Charley's friends sees him on a daily basis, they are able to provide a first hand overview of how he is feeling. Even though Josie is unable to see Charlie everyday, by leveraging the power of his social network, she is able to get a more complete view of his overall health.

2.1.3 Beyond the Virtual Housecall

Back in her office, Josie is using her "Patient Management" mashup to see the results of the input from Charley's social network along side his clinical data. Based on the data collected from his telehealth system, she notices Charley is running a fever. Josie studies the input from his friends via the "How do you feel?" gadget, who have also indicated that he is not feeling well. She notices several comments where Charley has complained of nausea. Reviewing his "Meal Planner", Josie notices that Charley indicated he ate a prepared snack of green apples and peanut butter that he purchased at a local grocery store. Looking at the information from the CDC gadget, Josie notices that the product Charley ate for lunch the day before has been recalled because of salmonella. Based on this information, Josie retrieves Charley's emergency contacts group from his social network and sends them an SMS message asking them to check on Charley right away and seek further medical attention.

This scenario demonstrates how technology is enabling better visibility and creating new channels of communication between patients and care providers on their own terms and schedules. The portability of applications across mobile devices and web sites along with improved access to these systems is untethering patients, enabling them to lead more active lifestyles while managing their conditions. Combining healthcare with Web 2.0 social networking technology, patients can provide additional context beyond physical readings to create a more comprehensive view of their overall health [2].

3 Proposed Solution: Leveraging Open Source and Open Specifications

Figure 1 provides a high level view of a system incorporating the remote monitoring services supporting the patient, the primary care network driving the health care delivery, and the extended care network of the patient. The system is organic in that it leverages a set of related standards, specifications and reference implementations.

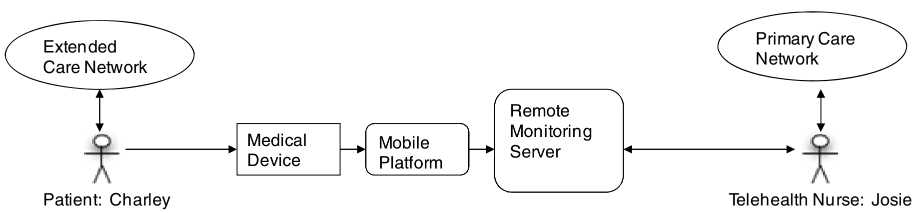

Fig. 1. Overview of the System Components

There are several standards and reference implementations that provide interoperability and act as accelerators for the intersection of these domains. We propose a solution based on two key enablers: the Continua Alliance specification [3] and the OpenSocial specification [4]. To quickly establish an ecosystem supporting these interfaces, the Stepstone reference implementation [1][6][7] jointly developed by IBM and the University of Florida was also selected for this proposed solution.

3.1 Integrated Services/Social Network Architecture

Stepstone (Figure 2) provides an end-to-end reference implementation, which enables device readings to be persisted for analysis and visualization. This enables a dynamic and modular environment from a device perspective. The current implementation does not have a similar approach to deploy user applications in the Web 2.0 domain to enable more social aspects and inputs for data.

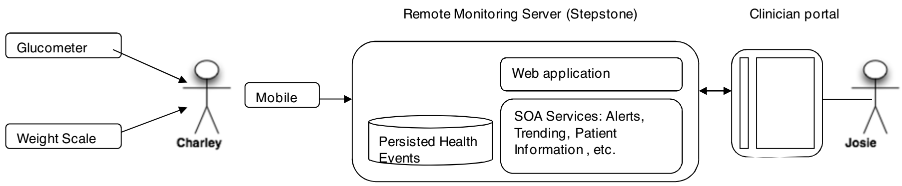

Fig. 2. Stepstone Architecture

Extending Stepstone to include social networking components from Shindig [5] adds in additional flexibility and configuration options. This section breaks this integration into several steps, building on the social aspects as Charley's needs evolve.

The first step will be the introduction of gadgets (Section 2.1) in the remote monitoring server domain. Figure 3 demonstrates an end-to-end remote monitoring scenario enabled with gadgets. The OpenSocial specification details the definition of the gadget, the gadget container that runs in the browser, and the server-side rendering and delivery of gadgets. The gadget container runs in the browser and manages the gadget interactions, call backs, as well as providing a common set of client APIs. The gadget server is responsible for parsing the gadget description and delivering the gadget to the container. This enables not only browser rendering of the gadget, but also an automatic service definition generation of the gadget, which makes for highly portable applications on the web.

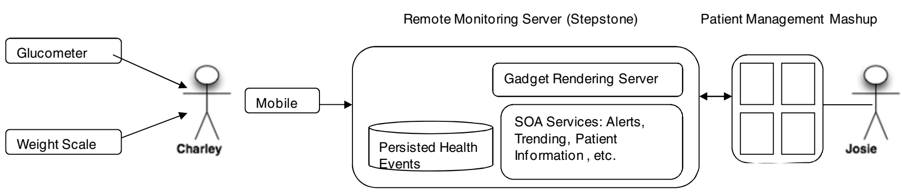

Fig. 3. Introducing Gadgets to Stepstone

Charley uses health devices connected to his mobile to capture physical readings which are then sent to a remote monitoring server (RMS) via web services. The Stepstone RMS provides a series of services including patient information, device readings, trending and analysis of this data. Clinicians are able to leverage a Mashup displaying Charley's progress through a series of gadgets. These clinical gadgets provide a portable interface into Charley's healthcare information. By adding the Gadget Rendering

Server to the RMS, a clinician can now leverage these gadgets by adding and removing components as Charley's care view changes.

In Section 2.1.1, Charley makes his social network available to his remote monitoring server. Figure 4 demonstrates the addition of the social network into the Mashup. The addition of the Social Gateway enables the RMS to make requests to Charley's social network on behalf of the remote monitoring server. The OpenSocial API supports the retrieval of Charley's profile information, his relationships and groups that he belongs to, as well as activities that he posted. Applications can now leverage Charley's profile as a source for accurate contact and address information or to view of his emergency contacts list defined by the social network. In addition Josie's views can now have an access to the applications that Charley is using. For example, the new application that was added to monitor meals is now exposed through his AppData. The RMS can retrieve this information and enable Josie to take advantage of this additional set of data as she makes decisions about Charley's care.

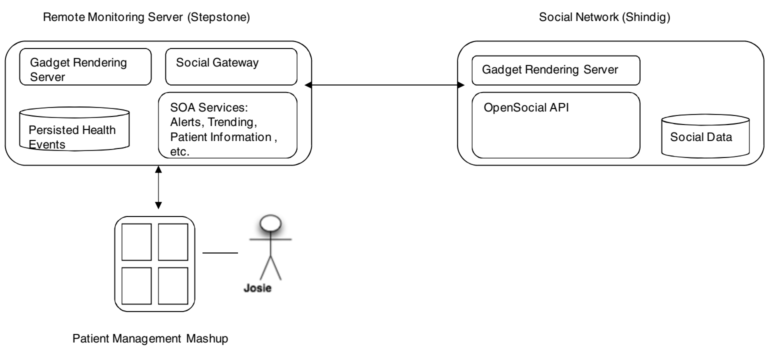

Fig. 4. Introducing Social Server

In Section 2.1.2, as Charley's needs changed, his social network offered additional details of his status and activities. In order for Josie to leverage this and get a broader view of Charley's status, the RMS must enable the gadget as illustrated in Figure 5.

1. A developer creates the new "I Feel Good" gadget, and hosts this definition on the RMS and an admin then registers this new gadget with the social network.
2. Josie sends a message to Charley through his social network indicating that this new gadget is available.
3. Charley adds the application and decides to share this new application with his extended care network. This is supported through the underlying OpenSocial APIs (shareApp) in the social network.
4. As users accept the application, the gadget is added to their view. The rendering server retrieves the gadget description from the RMS, and renders the application on the client.
5. The users in Charley's network start to record their view of Charley's status. These recordings are sent from the social network clients asynchronously to the RMS to persist them as events and to aggregate them into a consolidated, collective social network input ("effect").

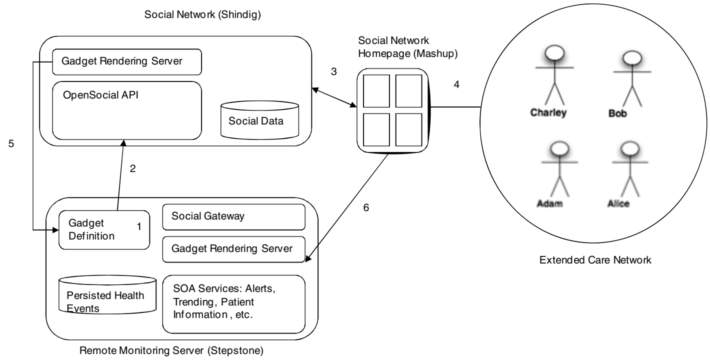

Fig. 5. Sharing Applications/Gadget lifecycle

Once this data is persisted, Josie can leverage the network effect of Charley's extended care network to gain new insight and corollaries into Charley's status through the lens of his social network.

These scenarios described above provide a simple introduction into the alignment of these two architectures. Since these were based on open interfaces and APIs, this solution can quickly scale outside of the prototypical project.

4 Conclusions and Ongoing Work

This paper presented a set of scenarios and a technical approach that demonstrates how social networks can be leveraged to improve patient care. While challenges remain, new and innovative solutions can, and are, being built today on top of rapidly maturing social networking platforms.

Enabling new and creative applications will improve the ability for medical professionals to deliver quality care by combining clinical data with a patient's own "network effect". As the economics of healthcare continue to come under pressure, providers will naturally look for opportunities to lower costs and increase quality. Web 2.0, social networking, open source, and open standards and specifications are the ingredients for the next wave of innovation in personalized healthcare.

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A Case Study of an Ambient Living and Wellness Management Health Care Model in Australia

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Abstract. The QSHI (Queensland Smart Home Initiative) consortium was established in Queensland Australia in 2006 for the purpose of promoting a model of health care based on ambient living and wellness management. This model was based on the adoption of smart home and intelligent assistive technologies. A technology research and development program was also established to promote independent living, improved quality of life and reduced unnecessary hospital admissions for the frail elderly, chronic illness sufferers and people with disabilities.

The consortium joined the technology industry, care providers, government and researchers to a collaborative Research & Development program to assist people and their families. The first Phase has been completed and on-going streams of research have been established. These included the establishment of a demonstrator Smart Home in a residential retirement and aged care complex in a metropolitan setting in Queensland, Australia.

This paper reports on the development of the model and outlines the project scope and experiences, the outcomes and learnings achieved, and details the planning considerations for future developments.

Keywords: Computing, Healthcare, Seniors, Telecommunications, Workforce.

1 Introduction

The interest internationally in the promotion of ambient living and wellness models of health care through the utilization of Smart Homes particularly for the frail elderly [1] is shared in Australia. The Aged and Community Care industry in Australia is facing many challenges including those related to consumer demand and supply of services, workforce availability and skill levels, and the geographical spread of the aged care population and of services. These challenges promote the need to investigate and implement new models of care delivery.

In 2006 a consortium of stakeholders was established in Queensland Australia with the aim of investigating new models of care delivery based on supporting independent living, improving quality of life and enabling new models of home care particularly for the frail elderly, chronically ill, and people with disabilities.

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This consortium also aimed to build a national and potentially regional capacity for research and development, commercialisation and adoption of assistive technologies. The focus of research was the issues of adoption and the benefits rather than necessarily developing technologies per se. Anticipated outcomes included better access to care for clients, financial savings for care providers and departments of health, national and state economic benefits, export opportunities and commercial benefits to stakeholder organisations.

2 Ageing

Australia shares the concerns of most countries regarding the impact of an ageing population. The pressures on health and aged care national service delivery budgets are demanding new solutions and models of care delivery.

Technology is anticipated to offer significant potential for equipping societies to respond to these pressures [2,3]. Applications include assisting aged people in extending active and independent lives, maintaining productivity and in delivering care in home and community settings. Globally there is an increasing level of activities, strategy development, research projects, and adoptions of telecare, telehealth, smart homes and assistive technologies by consumers and care provider organisations [4].

The application of these technologies has an array of added benefits including a reduction in the level of incidents of adverse events, providing support and new service interventions for conditions amongst the elderly such as chronic illness, falls, dementia, medication problems, wandering and social isolation.

3 Technology

Australia like many other countries has an interest in better enabling frail older people and the chronically ill to receive care in their own homes and delay or avoid moving into institutional care. Introduction of an array of new models of home care has raised challenges for the service sustainability and workforce availability and skilling. There is an ever increasing interest in the adoption of assistive technologies to support and enhance the service system and health workforce.

There is also a widespread recognition of the potential for technology to enhance the safety and independence of frail older people, enable access to quality care services and to extend their ability to remain in their own homes. Intelligent monitors can keep a continuous watch on vital signs, activity patterns, their safety and security. The technology can monitor indicators of their state of health, provide alerts to events such as falls, and give early warnings of potential problems. The technology can notice changes in activities and alert a carer. Monitoring devices can be more accurate guides to the health risks such as a heart attack than are the patient's symptoms, providing advance warnings and reducing unnecessary emergency callouts [5]. Home automation will enhance security, safety and independence at home [6]. This will help maintain quality of life and decrease the demand for carer support hours. Communication technologies will provide important benefits for people whose mobility is limited, or who live alone. Finally the various home automation and digital technologies can benefit the aged and the disabled, improving their quality of life by enhancing their independence.

On a broad scale other countries have embarked on research or demonstration models with the aim to implement assistive home technologies [7,8]. In a state of Australia a system of referrals from hospital admission to home care is in use [9]. There are similar initiatives around most Australian health jurisdictions for managing Emergency Department demand. Aged and Community Care service providers are actively investigating the use of assistive technologies to ensure effective service delivery.

The potential of technology to extend persons physical independence and thus enable them to remain living in their own homes for longer has the outcomes of affording individuals a more dignified life, and has the potential to save public and private money. In geographical diverse countries like Australia it has the great potential to bring services into communities and to individuals.

Research into adoption issues, return on investment, realisation of benefits, integration and interoperability is required to ensure a sustainable system. Current evidence indicates that the level of adoption of technology remains low. There appears to be many factors influencing this and these are seen to include awareness, attitudes of seniors to technology, design issues, telecommunications capacity, technical support, overall cost and uncertainty that benefits will be realised. The paradox of the increasing availability of intelligent assistive technologies and their low level of adoption is the main focus for the research of the QSHI.

An indication of the extent of new technologies available and related research is available from the web-site of the Center for Aging Services Technologies [10].A new centre in Ireland, Technology Research for Independent Living (TRIL) is using ethnographic approaches to better understand seniors' attitudes to technology [11].

4 Queensland Smart Home Initiative

The Queensland Smart Home Initiative arose from a plan for building a consortium in this domain. The first phase of the project involved building the research consortium based upon a high-level vision of the potential ICT and assistive technologies for care in home and community settings. A small number of organisations were selected to be approached to invite participation. Selection of organisations was based upon an assessment of complimentary skills and interests, and to avoid duplication. The organisations were selected in order to provide a balance of stakeholder interest. The organisations that committed to support the initiative included a department of health, a major aged and community care provider, a home care technology supplier, a smart home environment supplier, an association of owners and operators of aged and community care facilities, an aged care consumer organisation, a multi-national manufacturer of ICT componentary, a telecommunications company and two universities.

5 Projects

The QSHI has two major projects being the Smart Home demonstration site and a comprehensive Research Program. The Smart Home was designed to showcase local and international technologies and innovations to support independent living and home care, and to reduce hospital admissions and length of hospital stay. The Research Program was developed by the consortium partners and included the following main streams:

- Demonstrator Smart Home – involving gathering of feedback from stakeholder visits; this included consumers, carers, care providers and policy-makers.
- Hospital avoidance – minimising unnecessary admissions.
- E-communities of care - connected communities for enhancing communications related to health and well-being.
- 101 Smart Homes Project – 101 homes occupied by frail elderly or others with special needs that are equipped with telecare technologies.

6 Smart Home Evaluation

The QSHI's first Smart Home was opened in April 2007. The objective was to increase awareness, provide an educational resource and gather feedback from stakeholders. The site had around 250 visitors over 12 months and people visiting the Smart Home were invited to share their impressions. Each visit was hosted and the technology presented and explained.

A research project was undertaken to distil the vision, research needs, priorities and expectations of the stakeholder organisations [12]. The aim was to inform a collective vision on the potential of the Smart Home project and the development of a research program. This involved individual consultation with managers and senior executives of each of the participating organisations. Semi-structured interviews covered vision, what stakeholders would like to see in 3-5 years, desired outputs, desired projects, anticipated benefits and other impacts. This was followed by a facilitated 3-hour focus group workshop involving 16 participants from across the stakeholder organisations. These included care providers with first-hand aged care experience, technologists, e-health researchers, government aged care strategy and policy officials, telecare call centre operators (with first-hand experience of communicating directly with the aged in their homes), and representative of owners and operators.

There was an initial expectation that the care provider partner in the consortium would be happy for staff and residents to participate in research. This was not to be the case and in discussions the residents indicated that they had varied views on how relevant the use of technologies was to their own lives. The Smart Home location and access in an independent living unit (ILU) facility located in a large aged care campus posed challenges for gaining greater consumer participation in the research project.

Instead the data captured was the feedback of visitors to the unit. Visitors were from a broad range of stakeholder backgrounds including consumers, carers, care provider organisations and policy-makers.

The outputs of these activities were compiled into a draft vision, strategy and research program document which was then used as the basis for a further 2-hour focus group with stakeholders. The final draft was then further refined by a smaller group consisting of single representatives of the technology supplier companies and the university researchers before being circulated to the broader group for final comment.

7 Hospital Avoidance

The QSHI research program included an ambitious schedule of candidate projects. It was a logistic impossibility to make great advances across such a broad range of projects due to the limitation of QSHI participants all giving up time from their other demands and busy jobs. The most advanced project became the one around "hospital avoidance" or reducing unnecessary admissions of the elderly. This project attracted substantial support from a state department of health, a software developer and several universities. It attracted a large national competitive research grant which gave the project the benefit of dedicated professional resources.

It also provided a model for how other projects might work and be funded. The hospital avoidance project is currently underway in a central Queensland health district with the support of primary and secondary care providers.

The hospital avoidance project has a committed site involving both primary and secondary care providers. The requirements research has identified needs including provider directory, waiting lists for community services including government-subsidised home care packages, alerts to primary care providers about admissions or discharges of their patients, and discharge medication details for the patient's primary care doctor.

Smart homes and assistive technologies are closely connected to hospital avoidance through enabling earlier discharge or diversion from admission. In Australia the practice of public hospitals is to admit patients and not discharge if care at home is inadequate. Patients are less likely to present at A&E when telecare and telehealth is available in their homes. In circumstances when patients do present the A&E staff may be more confident of them returning to homes equipped with technology and similarly the technology may allow earlier discharges.

8 Findings

The data collected from interviews and the focus group discussion was subject to thematic analysis and results are presented in Table 1.

The developments and implementations for this project were extensively driven by care providers and government authorities. The research identified the need for technologies to be user friendly. Technology is often developed by young people who may not always be aware of difficulty older people have with eye-sight or dexterity. Older people, as with healthcare patients, are not always treated with respect and even more, as a partner in their own care. Indications are that if older people are involved in decisions such as selection of assistive technologies then there is a higher rate of successful adoption.

Care provider organisations and government are particularly interested in technology to assist in workforce issues. These include making aged-care a more desirable place of work, providing staff with efficiency and productivity tools, and improved work-force satisfaction and retention. Some functions that are labour-intensive could be aided or eliminated by technology. These include monitoring or taking vital signs. At-risk patients could be better monitored and care can be accessed across the huge distances in Australia.

It will be important to address privacy, security and trust in systems as well as identifying the skill sets and training required. If people feel unease then they may not use systems effectively.

Table 1. Themes and examples of comments from data gathered in semi-structured interviews and focus group discussions

Themes	**Issues**
Design	Need for user-friendly design, especially for elderly Need for research on elder-friendly design
Adoption	Need to involve seniors in acquisitions Need for delivery channels and support Need to provide quality response services
Care benefits	Need to enhance independence
Workforce	Need to promote benefits to policy-makers Need to enhance workforce productivity Need to assist in workforce shortages To assist in attraction and retention
Distance and travel	Needs to work across distance Needs not to require broadband for remote sites
Funding	Government funding needed for research and pilots Need to have Medicare items for technology
Education/awareness	Need for quality research to drive policy Need to promote existing evidence Need to promote the range and availability
Privacy and security	Critical for systems to be trusted

9 Experiences and Lessons

The QSHI has been operating since 2006 and during that time has gained experience and derived lessons from the projects. The experience of this first phase has informed the development of the next Phase which will be launched later in 2009. A reflection of these follows.

9.1 Focus and Constraining of Scope

The QSHI consortium developed a large Research Programme incorporating the ideas of the diverse organisations joined it. There was resourcing and capacity to deliver on only a small sub-set of these streams of proposed projects. Consequently it may have left some partners feeling that their ideas and needs were not addressed.

9.2 Awareness of Grant Processes

Some partners had experience of research grant processes while for others this was something they were not confident with. Consequently some partners made major commitments and they enjoyed the resourcing for projects from grant successes while other partners were either not as well placed to commit resources or less comfortable with grant processes.

9.3 Governance

Most of the QSHI focus was on projects and as a consequence governance arrangements remained under-developed. A lack of clarity about governance restricted effective planning and decision-making.

The above issues informed the next phase of the QSHI. A major feature is the establishment of a Foundation to underpin the research programme through providing governance and resourcing. This has financial commitments from government, universities and a major technology component manufacturer.

10 Discussion

To support the Queensland Smart Home Initiative's objectives a model for research and development has been derived from the initial consultations and focus groups with representatives from a broad range of stakeholder organisations. Although basic technology either exists, or has been adapted, to set up a homecare environment there is also the potential to support a wider community, particularly those in need of higher levels of care which will only be realised through further advances. At the initial stage the main focus will be on the technological improvements of advanced electronic technologies that can be adapted to suit the homecare setting. After implementation and deployment a shift towards understanding the social issues and any perceived barriers will be highly beneficial to ensure widespread take-up and adoption.

A model was derived from the consultation and recognises that different priorities and outcomes may prevail depending on the perspectives of the stakeholders involved. To undertake effective research requires that we push the boundaries of knowledge. Hence the determining factor for each research stream is the category where there is the greatest need to advance knowledge to meet the stated aims, i.e. major advances in technology, people, workforce or organisations.

The necessity to take this proposed method of approach is derived from the particular constraints that apply to a smart home that can ensure it will be commercially viable and socially acceptable. Assistive Technology refers to the devices that can be used by persons with sensory, motor and cognitive limitations to achieve greater independence and self-reliance. Typically assistive technology (AT) refers to those devices that are designed with electronics, microprocessors and high performance materials which allow: powered mobility, augmentative communication, environmental control and the use of microcomputers. These devices usually require training for use and customization to fit it to the individual's needs. Hence, this technology is geared towards the needs of individuals with particular disabilities often requiring more expensive 'bespoke' solutions to give them, as far as possible, an equal quality of life when compared with those currently more able. By contrast the smart home has to provide cost effective solutions that are not only more generic and ubiquitous in nature but conform to the local healthcare regimes. Furthermore, many of the users, particularly the elderly, do not see themselves as in need of specialised support and hence the technology must wherever possible fit in with the commodity electronic devices that people are more familiar with.

Similarly the currently available health and community care workforce in Australia presents barriers to the effective implementation of available technologies in service provision. These constraints have been investigated in the operation of the Smart Home.

The authors believe it is these constraints that will determine the success and adoption of the advanced technologies employed in the smart home and in models of self and assisted care. The OSHI has included projects that specifically address these issues. This social-technical approach is emphasised in a recent UK report "Time to Care - An overview of home care services for older people in England," [13] which endorses the use of technology to reduce the dissatisfaction of the typical 15 minute home care visit yet emphasises that "Failure to listen to what people really need, and respond to this, results in missed opportunities to promote independence and to help people live full and rewarding lives." Furthermore, "As the numbers of older people grow, councils must reshape services to support people living at home with more personalised care. Doing more of the same will not be enough." That is we need to find new ways of organising services so that people have a better range of choices. Research programs must address these issues and the proposed three stream approach proposed here should provide a more balanced view. Privacy and security of information are particularly important aspects which need to be part of research programs in this field and are something the QSHI has as a priority [14].

11 Conclusion

Most people have become familiar with and have adapted to technologies such as those now available in motor vehicles. Technologies such as central locking, electric windows, climate control, electric adjustments for seats and mirrors, hands-free mobile telephones, GPS, and ease-of-use entertainment systems are regular features. In the Australian aged and community care service delivery models it is surprising that little of that technology has yet made its way into individuals homes or as a integral part of service delivery. Utilization of technology to assist a person to remain as independent as possible in their own homes and in their communities is essential and has the potential to increase the numbers of frail elderly persons living in communities.

This paper reports on a case study of forming a consortium of stakeholder organisations to build Smart Homes for use by frail elderly, chronic illness sufferers and people with disabilities. It outlines the potential benefits of such collaborations as well as the requirements for effective consumer and workforce engagement. The range of research programs undertaken using the homes as a platform have indicated the important role assistive technology can play in promoting health and wellness models in self and assisted care.

The Queensland Smart Home Initiative aims to contribute to the national and international agendas for quality care and independent living through assistive technologies based upon the research program developed through stakeholder consultation.

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Market Potential for Ambient Assisted Living Technology: The Case of Canada

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Abstract. An Ambient Assisted Living (AAL) environment is an integration of stand-alone assistive technologies, with elements of smart homes, and telehealth services. Successful development of this emerging technology will promote the ability for older people to live independently and age in place. This paper focuses on the socio-technical challenges associated with implementing the AAL market with specific reference to Canada. The strategy used to gather information was a case study design. Market facilitators include the vast Canadian geography, the number of older people living in rural communities, and the development of several provincial initiatives aimed at enabling seniors to remain independent. The principle of universality in Canada's healthcare system bodes well for these technologies, as AAL has the potential to assist in equalizing services to these communities. Barriers include fragmentation of the market, where in Canada more than 100 different health authorities serve individuals across ten provinces and three territories.

Keywords: gerontechnology, health monitoring, smart homes, aging-in-place.

1 Introduction

Aging in place and remaining independent in one's home is a goal held by the majority of older people as they age [1]. Interestingly such a goal is congruent with efficient health care delivery because care for individuals in the home is less expensive than in institutional health care settings [2]. Using technology to meet this goal is the focus of current research within the Ambient Assisted Living (AAL) realm. The general purpose of AAL is to provide individualized support services and health care to older people. Successful development of emerging AAL technology will promote the ability for older people to adapt to their environment [3], live independently, safely, and age in place.

1.1 Ambient Assisted Living

An AAL environment is an integration of stand-alone assistive technologies, with smart home innovations, and telehealth services. In particular, this involves systems

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for monitoring older people at home and a range of services from traditional community alarms to the passive monitoring of individuals using multi-sensor data acquisition technologies [4]. Telehealth is defined as using information and communication technologies (ICT) to assist health care practitioners with diagnoses, treatment, consultations, and patient education [5]. This paper draws on work carried out within SOPRANO (Service-oriented Programmable Smart Environments for Older Europeans), a European Union funded project to develop such an ambient assisted living system. SOPRANO is an international consortium of corporations, service providers, and academic institutions with over 20 partners from countries including Greece, Germany, UK, Netherlands, Spain, Slovenia, Ireland, and Canada.

While there has been much research and speculation regarding the widespread adoption of SOPRANO-type technologies in the United States and Europe, knowledge of how this market may emerge is still in its infancy. The case of Canada is particularly interesting. Surveys in North America have found a strong desire for inclusion of health services into AAL technologies [6]. Additionally, new market projections on the integration of nutrition, health monitoring, grocery shopping, emergency services, and telemedicine have been viewed positively [7]. The current level of technology use however (e.g. existing technologies such as alarms or personal response systems) in Canada is relatively low and the question remains whether there is potential for the AAL market in Canada.

This paper is not intended to focus on the hardware or software associated with these systems, but rather will explore the notion of AAL as a potential equalizer to health services via the examination of its market potential within the Canadian context. This socio-technical approach allows us to develop a better understanding of the usability and challenges faced by those individuals who will eventually interface with the system. Here we will begin with an examination of the Canadian health care system, followed by a discussion of the facilitators, barriers, and market potential of SOPRANO-type technologies in Canada.

2 Methodology

A case study design was used to gather information concerning the potential for ICT adoption in Canada. Given that the ICT industry is in the midst of rapid expansion, our approach must be viewed as ideographic, meaning the data collected is unique to time and place. The data was gathered between September and November of 2008. Internet searches were performed to yield product information, while numerous government websites such as Health Canada and the British Columbia Ministry of Health were consulted to accumulate policy and program information. Additionally, phone calls were made to identify agencies available for providing financial assistance to Canadian seniors with regards to ICT-based services. Our team of six researchers reviewed the data collectively and identified the themes most salient to the development of AAL technologies in the Canadian setting.

3 Health Care in Canada

The current state of the Canadian Health Care system is a product of the Canada Health Act, introduced in 1984 by the federal government. This system will be described here in detail as its principles provide a moral and ethical framework that may prove to be a key facilitator in the development of the AAL market in Canada. All ten provinces and three territories adhere to a set of five overarching principles: universality, public administration, comprehensiveness, portability, and accessibility [8]. Universality in particular mandates all insured residents are entitled to the health services provided by the provincial or territorial health care plans under uniform conditions. These five principles form the publicly funded program known as Medicare, were designed to ensure all citizens and permanent residents have reasonable access to medically necessary hospital and physician services.

While the Canada Health Act sets out the defining principles regarding the delivery and financing of medical care, such services are the responsibility of each province and territory [8]. In order to receive federal health care funding, each province and territory must adhere to the principles described. The delivery of health care services is regionalized further into smaller organizations called health authorities [9]. Although each respective provincial Ministry of Health outlines province-wide goals and standards, the actual planning, integration, and delivery of medical and social care services are the responsibility of the health authorities. For example, in British Columbia, the Ministry of Health Services oversees five geographical health authorities whereas Ontario's Ministry of Health and Long Term Care oversees fourteen health authorities that are responsible for local service delivery [8]. Interestingly, while the Canada Health Act may be viewed as a facilitator in principle, the manner in which services are delivered may be seen as a barrier to the initiation of the AAL market.

Provinces and territories also finance additional services and programs outside of the Canada Health Act definition but within their health insurance plan legislation [8]. As a result, there are some variations between provinces in the services provided and covered through public funding. These are often geared towards specific groups including older adults and those with low-incomes. For example, within British Columbia there are no publicly funded provincial government agencies or ministries that administer programs to subsidize ICT-based services for seniors [10]. However, Alberta's Ministry of Seniors and Community Supports administers a one-of-a-kind program called the Special Needs Assistance Program for Seniors. Under this program, low-income seniors who have exhausted all other government resources, and still have financial difficulties, may be eligible for funding of one-time extraordinary expenses. This program provides a maximum of $5000 of funding per year for seniors. To be eligible, the applicant must show that they have applied to other benefit programs, have resided in Alberta for a minimum of three months, have completed the Special Needs Assistance Program application form, and fall within current annual income eligibility guidelines.

Given the vast geographic differences in Canada, particularly the urban and rural disparities, Canada Health Infoway is recommending the adoption of telehealth to assist in the reduction of health care costs [11]. These examples display that such programs may act as either barriers or facilitators towards the implementation of SOPRANO technologies. On one hand, there is a potential that AAL expenses could become subsidized, on the other, a comprehensive bureaucracy may inhibit the actual number of users who may benefit from accessing such programs.

4 Facilitators

There are number of facilitators driving the adoption of ICT-based services in Canada. First, Canada has an aging population, and the percentage of older individuals over the age of 65 is projected to grow from its current 13% of the population to an estimated 21.4% by 2026 [12]. In fact, Canada leads the industrialized world with regards to its rate of increase in the older adult population. It is estimated that between the year 2000 and 2030, there will be a 126% increase in this demographic [13]. This is considered to be a facilitator due to the fact that the expected AAL market is to be made up of a proportion of Canada's over 4.5 million seniors.

Second, while much of the population lives condensed in close proximity to the U.S. border, geographically Canada is the second largest country in the world, with a total land area of 9,093,507 km^2 [14]. Depending on which Statistics Canada definition is used, between 22% and 38% of Canadians may be classified as living in remote or rural communities [15]. Geographic location has been established as a determinant of health and many surveys display a dichotomy whereby residents of remote and rural communities experience poor health in comparison to their urban counterparts [16]. One potential factor playing a role in the unmet healthcare needs of rural residents could be proximity to a physician. In a study by Ng, Wilkins, Pole, and Adams it is reported that there is less than one physician per 1000 residents in rural regions, compared to two or more physicians per 1000 residents in large urban centers [17]. Further, two-thirds of rural and small town residents live within 5 km of a physician, while 7 percent live more than 25 km. Finally, the special case of the northern remote regions should be mentioned. Here it is reported that two-thirds of individuals live more than 100 km from a physician. Translated this leaves between 6 and 11 million Canadians at risk of poor health due to geographic location. Recall that under the Canada Health Act's principle of universality, all insured residents of a province or territory must be entitled to Medicare services [8]. This bodes well for AAL technologies as they have the potential to help equalize service provision to insured residents [18]. More specifically, AAL has the potential to increase access to one's health and social network by electronically reducing the distance between both service providers and family members.

Third, Canadians have been very receptive to the use of new technology. This is evidenced in the growth in Internet use from 12.7 million users (or 40.3% of the total population) in the year 2000 to 28 million users (or 84.3% of the total population) in 2007 [14,19]. These general policy and population features may all contribute to the facilitation of ICT growth in Canada.

Fourth, examining the issues of medication compliance among older adults in Canada, demonstrates how even a single component of the SOPRANO system has the potential to reduce costs to the health care system. For example, Samoy and colleagues have reported that 25% of hospitalizations in British Columbia's largest hospital are drug related [20]. Further, 16.2% of these drug related incidents were the result of non-compliance. Non-compliance is simply, the inability to use a medication as it was prescribed, and in elderly populations, noncompliance rates run approximately 60% [21]. The overall cost of non-adherence in the United States in 1997 was estimated to be approaching $100 billion [22]. Given that Canada's population is approximately one tenth the size of the U.S., and factoring in a modest 3% inflation rate in the healthcare sector, it is possible that costs of non-compliance in Canada in 2008 may have been as high as $14 billion. Taking the scenario described into consideration, the remote monitoring of medication use in SOPRANO, certainly possesses the potential for widespread utilization.

Finally, there is a trend within numerous provincial health ministries towards care in the home rather than in an institutional setting. While the Canadian Home Care Association has argued that financing has yet to follow government rhetoric in this area, several recent government strategy frameworks suggest a more promising outlook [2]. For example, the Healthy Aging and Wellness Working Group, a consortium representing most provinces, have outlined a strategy for healthy aging in Canada [23]. This strategy includes supporting and caring in the community, as well as enabling seniors to remain independent by promoting self-care in the home. Additionally, the government of British Columbia has recently published the *Seniors Healthy Living Framework*, where under the cornerstone of healthy living, the province is searching for new tools and supports for those who are providing in-home care to seniors [24]. Further, in the province of New Brunswick a long-term care strategy has been developed. Some of the key goals include a desire to reduce the burden of care among family members, to reduce the need for long term care services, and to increase the range of options available to manage care in the home [25]. An AAL environment such as SOPRANO may be viewed as one potential tool to assist and achieving these goals. Overall, these facilitators justify our call to examine the market potential within a socio-technical framework. It is simply not worthwhile to progress with the development of these technologies in isolation of the social context in which they will be embedded.

5 Barriers

On a general level, a number of constraints towards ICT adoption exist. The major barrier is clearly the fragmentation of the delivery of health care in Canada. While the country has Health Canada at the Federal level, the realm of responsibility is to establish criteria and conditions to be fulfilled by provinces and territories. These jurisdictions may receive cash contributions by way of the Canada Health and Social Transfer payment [8]. Thus, each province or territory has a different strategy to administer health initiatives at a local level. In Saskatchewan, for example, health is delivered regionally via 12 provincial health authorities. This feature may act as a constraint because companies developing technologies that may improve health and health care delivery cannot look to Canada as a single market. In fact, it is not unlikely that each of the country's over 100 health authorities [26] would have to be dealt with individually.

Additionally, with regards to the adoption of innovation, Canada currently ranks 13th out of 17 industrialized nations and has been a below average performer since the 1980's [27]. This is problematic since emerging technologies such as AAL are subject to further upgrades as the technology develops. Thus countries that do not adopt innovative technology early run the risk of being one or more generations behind and always trying to catch up.

Finally, the key barrier in the socio-technical framework concerns itself with policy and legislative implications. Through ICT-based services such as telehealth it is now possible for patients from remote or isolated areas to be treated by out-of-town physicians. This situation will give rise to the question of licensing and whether the physician is licensed to practice in one area to the next. Currently there is no inter-jurisdictional agreement on licensure and regulation of practice and standards on the use of telehealth between patients and physicians [28]. Silverman has identified four challenges relating to policies that would prevent the widespread proliferation of telehealth [29]:

1. The lack of doctor-patient relationship agreement or protocol, particularly for online telehealth services. There is a need for agreement on what constitutes informed consent for online medical services.
2. There is a lack of protection from liability and malpractice surrounding telehealth and practice in cyberspace. Specifically, there is no jurisdiction on licensure regarding who is qualified to provide health services. It is unclear whether physicians would currently be protected under the malpractice insurance policies for allegations arising from telehealth care.
3. There is a lack of standardization of practice and patient privacy for electronic health information and telehealth.
4. There is no legislation on the reimbursement of service for telehealth and Internet health consultation.

In using a socio-technical framework, barriers have emerged and are highlighted which may not have otherwise been salient. Thus, it is important to continue looking at such items from a multidisciplinary perspective and include those stakeholders in the policy, research and development, and end-user realms. In short, there is little use in forging ahead with the development of AAL technologies, without careful consideration of these issues.

6 Market Potential

In Canada, the market for AAL may progress by means of two different pathways. First, the subsidy/reimbursement path, where some organization (e.g. government, charity, corporation) pays all or a portion of the costs associated with the implementation and maintenance of an AAL environment. Second, AAL has potential to emerge within the private consumer market. Both of these paths hold great promise for the implementation of AAL generally and the SOPRANO system specifically in the Canadian context.

To gain insight and understand the subsidy/reimbursement path, an examination of Canada's Electronic Health Record provides a potential roadmap. As is true with any innovation, the concept of an electronic health record, like AAL, was at one time only an idea. The Federal Government of Canada formally recognized the importance of the Electronic Health Record in 2001 with the development of Health Infoway Incorporated [26]. Subsequently, at the provincial level in British Columbia, an agreement was reached in 2006 between the government and the British Columbia Medical Association (BCMA) to standardize and facilitate the implementation of electronic medical records [30]. To provide contrast and set the tone, the Canadian Home Care Association [2] has clearly lobbied for change in the domains of home care and informal care with less than spectacular results. The political power of the BCMA [31] which represents physicians, medical residents, and medical students in British Columbia is by comparison, vastly superior. Considering this organization represents some of the wealthiest members of the province, the Physician Information Technology Office (PITO) may be viewed as an absolute coup d'etat. Under the PITO program, the government has chosen six vendors eligible for reimbursement and physicians simply choose one of these vendors to implement the electronic medical record in their office [32]. The costs of implementing the program include one time implementation costs and annual operating costs, both of which under the PITO program are funded at the 70% level by the provincial government. This program provides clear evidence of the funding bias towards medical and acute care in British Columbia and in Canada. Thus from a strategic perspective, if the reimbursement channel is sought, market exploitation has the best chance if it could in some manner be aligned into the realm of medical care.

It is not beyond comprehension that a private market for AAL solutions may exist in Canada. Consider, for example, that the number of Canadians over 45 years of age, caring for seniors has increased from 2 million to 2.7 million between 2002 and 2007 [33]. If affordable systems are developed, it is not unlikely that these caregivers would be willing to pay for such a service. Another factor to be taken into account in the private market is the usability of technology. To illustrate, the total number of consumer electronic returns (where no trouble in the device is found) in the United States market totaled $13.8 billion [34]. It is clear then, that if AAL technologies are to successfully penetrate the consumer market, the focus must be on developing user-friendly technologies that will integrate seamlessly with existing devices and networks.

While a number of barriers have been identified, many promising developments are currently taking shape in Canada that may mitigate their detrimental effect. First, Canada may be poised for change as 2007 was a record setting year in terms of ICT mergers and acquisitions in the Canadian market [35]. The benefits of these changes will translate to economic gains in the long-term and will enable Canada to take advantage of its ability to innovate in the future. Second, the 2009 Canadian Federal Budget outlines new investment that bodes well for the Canadian technology sector [36]. This Budget calls for $750 million to be invested in leading-edge research infrastructure through the Canada Foundation for Innovation. Moreover, an additional $500 million is to be spent by Canada Health Infoway to encourage the implementation of Electronic Health Records. This is relevant because AAL is a logical step beyond the Electronic Health Record in terms of the integration of health care. In conclusion, there is great potential for AAL systems such as SOPRANO in the Canadian market and such potential may be realized most efficiently if future research continues to pay attention to the socio-technical framework.

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An Ontology-Based Actuator Discovery and Invocation Framework in Home Care Systems

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Abstract. Home care systems need to be personalised to meet individual needs, and must be easily adjusted as the user's symptoms develop. Care policies (i.e. Event-Condition-Action rules) can be used to specify care services, facilitating changes in the behaviour of a home care system. Context modelling allows a user to specify the trigger and conditions of a care policy, using high-level context rather than raw sensor data. The actions of a care policy are, however, still dependent on the implementations details of actuators. We propose a framework that allows the actions of a care policy to be specified abstractly using human-understandable concepts. The framework takes care of discovering and using specific actuators, hiding the low-level home networking details from ordinary users. It therefore makes personalisation and modification of home care systems more accessible to ordinary users, requiring very little technical knowledge.

Keywords: Assisted Living, Home Care, Ontology, Service Discovery, Service Invocation.

1 Introduction

Increasingly, providing care at home is seen as a promising alternative to traditional approaches such as nursing homes or sheltered housing. Building and evolving home care systems present significant research challenges. A 'one size fits all' solution is unsuitable. Home care systems are deployed on a large scale, individual care needs will differ, and conditions may change over time. For individuals and for changing circumstances, a home care system must therefore be customisable by non-technical people such as care professionals. Existing home care solutions do not address this issue. In commercial off-the shelf telecare products, functionality is often fixed in special-purpose devices and is not easily customisable. Research prototypes of home care solutions are often hard-coded.

Policy (i.e. rule) based home care systems are promising in making it easier for end users to modify the behaviour of a home care system. A typical care policy consists of an event (i.e. trigger), conditions and actions (otherwise known as ECA). When some event happens, if the conditions hold, then the actions are performed. By changing the rules, the behaviour of the home care system can be modified. Rule-based home care has been investigated in various research projects [1, 2, 3].

In policy-based home care, the events and conditions are often considered together and are defined as context [4]. Home care systems usually do not make use of raw

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sensor data directly. Instead, raw sensor data is interpreted or aggregated to produce high-level context. The behaviour of a home care system can then be expressed as rules that invoke actuators on context changes. To achieve interoperability among the components of a home care system, an ontology could be used as the basis of a common understanding of context [5]. By using high-level context, care policies need not be affected by differences in specific sensor technologies.

The actions of a care policy, however, are still tied to specific technologies and configurations of the actuators. In a care policy, the actions must state which actuators should perform what operations and with what parameters. The definitions of operations and parameters will vary a lot since different actuators with the same functionality may use different protocols, and services developers may define operations differently. As an example, a lamp could be controlled by EIB/KNX (European Installation Bus) or by X10; these have different APIs. And more complex actuators have an even greater variability in how they are controlled.

Existing solutions to specifying actions often rely on developer-defined service interfaces [6], assume a set of predefined services [1], or consider that an administrator can somehow pass the low-level protocol-specific parameters to the ordinary user who can supply them when editing the rules [2]. None of these is a good solution with regard to deployment of home care systems. For the first approach, actuator developers may define service interfaces differently. For example, two UPnP alarms may be controlled through completely different interfaces. For the second approach, having predefined services limits the deployment of new actuators. For the third approach, the users have to understand some low-level networking protocols. This is because various home network technologies use different operation names and require different sets of parameters for the same functionality. These protocol variations are not hidden from the users. For example, switching on a lamp may use the *On* command in X10, supplying the house code and device code of the lamp as parameters. UPnP may require the method *SetDeviceState* with parameter *DeviceState=on*. Changes in the configuration of actuators (e.g. method of connection or setting) may require changes in care policies. This makes adjustment of home care systems unnecessarily cumbersome and difficult.

We propose an ontology-based framework for actuator discovery and use to enable protocol-independent action specification. Ordinary users have a mental model how an actuator should operate, much as they view driving a car. The user should not have to bother with the technical details of the car, instead just performing standard operations. This concept of common operations should also apply to actuators in home care. The operations of actuators should therefore be modelled in an ontology. Based on this, actuators can register themselves with a semantic service discovery module. Actions in a policy rule can be specified using abstract operations and parameters. At run-time, the semantic discovery module searches for concrete actuator instances. Mapping from abstract actions and parameters to protocol-specific actions and parameters can then take place before executing the actions.

The purpose of our framework is to support end-user programming of home care systems by hiding the technical details of actuators. Just like developers need to write code to infer high-level context, developers also need to write protocol-specific handler code to deal with the mapping of abstract actions and parameters. However, only high-level context and abstract actions are visible to end users.

Section 2 of the paper presents an ontology of actuators for home care. Section 3 describes the design of a system to support actuator discovery and invocation, while section 4 discusses the implementation. Section 5 reviews related work on this topic. Section 6 concludes the paper and describes future work.

2 An Ontology for Actuator Discovery and Invocation

Actuator operations are modelled using the following concepts: *Actuator*, *Service*, *Operation* and *Parameter,* as shown in Fig. 1. An actuator provides some kinds of services. A given service could be also provided by alternative actuator designs. A service supports one or more abstract operations. Each operation has zero, one or more parameters. These concepts are part of a larger home care ontology. For example, *Actuator* is a subclass of *Device* class, which has *Sensor* as a subclass. A device can have properties such as *Location*.

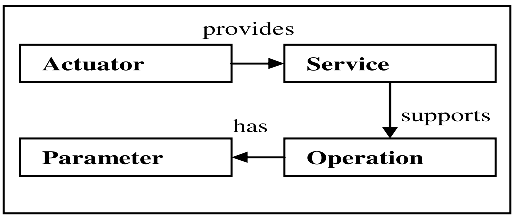

Fig. 1. Core Concepts of The Actuator Ontology

We represent our ontology using OWL (the Web Ontology Language), with each concept represented as an OWL Class. A hierarchy of actuators has also been defined. Subclasses of *Actuator* include *Alarm*, *DVDPlayer*, *Light*, *MobilePhone*, and *TV*. Some subclasses are further divided. For example, *DimmableLight* is a subclass of *Light*. A hierarchy of services is defined similarly. For example, *LightingService* and *DimmableLightingService* are defined, corresponding to services provided by the *Light* and *DimmableLight*.

Since only the abstract operations supported by actuators are relevant, operations are modelled using *Operation* class and parameters using the *Parameter* class. Specific actions supported by the actuators are instances (individuals in OWL terms) of the *Operation* class. For example, *SendSMSTextAction* is an individual of the *Operation* class. *RecipientNumber* and *TextContent* are both individuals of the *Parameter* class that could be used by *SendSMSTextAction*.

An OWL class can also have properties, typically a *DataType* property or an *Object* property. The first links an individual with data values while the second links one individual with another individual. For example, the Object property *hasLocation* links a *Device* individual with a specific *Location* individual.

To encode low-level protocol details about how to invoke a specific actuator, a *DataType* property is defined for an *Actuator* class. The *hasRAI* property links an *Actuator* individual with a string that represent the resource access identifier (RAI) to access the service provided by an actuator. This property defines the protocol and device (or service) identifier, separated by colon. This identifier uniquely distinguishes actuators using the same protocol and will correspond to different values in various home networks. For example, the RAI of an X10 living room light might be 'X10:b1', identifying the house code and device code. The RAI of a UPnP alarm might be "UPnP:fallAlarm", identifying its UDN (Unique Device Name).

3 Architecture of Actuator Discovery and Invocation

The overall architecture of policy-based home care is depicted in Fig. 2. Users specify care policies using a *Policy Wizard*. Sensor wrappers gather raw sensor data from sensors, convert them into entity properties (similar to the sensor wrappers in [5]), and store them into a knowledge base. The context server performs further reasoning based on facts in the knowledge base, and generates high-level context information. Changes in entity properties (i.e. context changes) are sent through an event service to the policy server. The policy server checks incoming events and environment state against the triggers and conditions of the rules; this decides whether to execute the policy actions. If execution is required, the policy server sends commands through event services to invoke actuators. (The policy server also performs other tasks as such refining high-level goals into policies and handling conflicts among policies.)

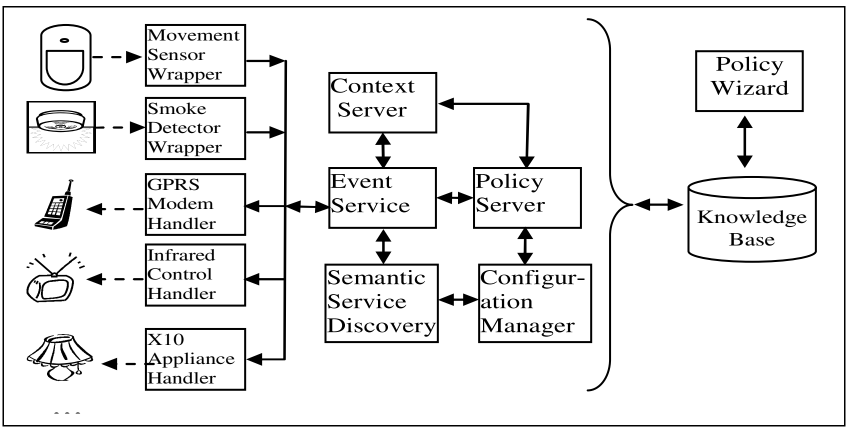

Fig. 2. System Architecture for Policy-Based Home Care

To discover specific actuators and protocol-specific parameters, the policy server consults the configuration manager and the semantic service discovery module. The event-based communication paradigm decouples sensors, actuators and the policy servers, so that changes in one of them will not affect others. The following section describes actuator discovery and invocation in detail. Using an ontology in service discovery and invocation involves the following steps: registering actuators, specifying actions in a policy rule, and run-time invocation of actuators.

3.1 Registering Actuators

When an actuator is installed in a home care system, its capabilities are registered with the semantic service discovery module and stored in the knowledge base. The latter represents actuators as individuals of specific classes. For example, the description of a lamp in the living room includes the actuator class it belong to (*DimmableLight*), its location (*LivingRoom*), its RAI (X10:b1), its manufacturer and other information.

Actuators may use different types of home networks. Some network technologies have built-in discovery mechanism. For example, UPnP defines how devices can be discovered and controlled programmatically using an API. Software agents can listen for UPnP discovery events and automatically register/unregister actuator capabilities in the semantic service discovery module. For actuators using home networks without a service discovery mechanism, a graphical tool can allow users to manually register devices in the knowledge base.

3.2 Specifying Actions

The policy wizard makes it easy to specify care policies. To specify an action, the following elements need to be specified: actuator, action and parameters. Specifying an actuator using a concrete RAI value essentially hard-codes which specific one is used. Instead, a set of conditions is specified that an actuator must satisfy. Currently the conditions are stored in a device variable held by the policy system. A device variable has a name and a definition that acts as a placeholder for a specific value. The name of the variable is referred to in a policy action. The conditions include the class that the specific actuator belongs to and a set of property restrictions.

A SPARQL query string is generated to represent the conditions specified by the user. (SPARQL, http://www.w3.org/TR/rdf-sparql-query, is the language used to query RDF-based documents.) Below is a sample SPARQL query to find the RAI of a living room light that can be dimmed:

```
SELECT ?RAI
WHERE {
 ?ins a configuration:DimmableLight.
 ?ins configuration:hasLocation
    configuration:LivingRoom.
 ?ins configuration:hasRAI ?RAI.
 }
```

Based on the class of the desired actuator, the policy wizard retrieves from the ontology the supported abstract operations and associated parameters. These are presented for the user to make a choice. This makes sure that only actions and parameters supported by an actuator are specified in the policies. This helps to avoid errors and reduces the user's learning burden.

3.3 Run-Time Execution of Actions

Three steps are followed when a policy action is performed: find the specific actuator to execute the action, map the action and parameters to protocol-specific ones, and finally execute the action.

The semantic service discovery module executes the SPARQL query defined by the device variable. The RAI property of the actuator found is extracted. The policy server then constructs a system event using the RAI, the abstract operation and the parameters. The protocol and the actuator identifier of the RAI are stored in the event properties. Finally the policy sends out this event through the event service.

Each home network protocol handler registers its interest in certain type of events by supplying an event filter to the event service. The event filter includes a condition on the protocol property of an event, so an individual handler receives only events associated with its protocol (e.g. *protocol=UPnP*). The *device_identifier* property of an actuator event is used by the handler to find the specific actuator to execute the action.

Individual actuator handlers also map abstract actions and parameters to protocol-specific ones before execution. Although these handlers have the same interface structure, the complexity of mapping the action and parameters varies a lot according to the network technology. For home networks such as X10, the semantics of operations are straightforward, so the mapping is easy. For other home networks, an automatic mapping may be difficult. For example, various developers may define differently the operations to activate an UPnP alarm. They may give different names to the action and may also use different state variables as parameters. Furthermore, one abstract operation may map to several UPnP actions. It is therefore necessary to rely on a protocol-specific actuator event handler to perform these mappings. Developers need to write specific code for this. The users of policy wizard do not need to be aware of this mapping. In order to specify the rules, they only need to know the abstract concepts present in the common ontology. Architecturally, when an actuator is installed into a home care system, the corresponding actuator event handler needs to register with the event service and be ready for the execution of protocol-specific actions.

4 Implementation and Evaluation

The policy-based home care system has been design using the OSGi platform as the basis (http://www.osgi.org). Knopflerfish (http://www.knopflerfish.org) has been used as the implementation of OSGi 4. Communication between the policy server, sensors and actuators is supported by an event service (EventAdmin), provided by OSGi. Wireless sensors from Visonic (http://www.visonic.com) are used to detect conditions such as movement, flooding, smoke, bed occupancy and door opening. A standard wireless receiver has been interfaced to a PC using a USB adapter.

The ontology has been developed using Protégé (http://protege.stanford.edu). Semantic service discovery and invocation has been implemented using the Jena semantic web framework (http://jena.sourceforge.net) and integrated with the existing policy server. The following protocol-specific event handlers have been created for mapping abstract to protocol-specific levels, and for executing actions:

- *X10* for controlling home appliances using an X10 network
- *UPnP* for controlling devices in a UPnP network
- *IRTrans* for controlling audio and video equipment such as TVs and DVD players using the IRTrans® infrared control system
- *SMS* for sending and receiving text messages using a GPRS modem.

The policy wizard has been enhanced to support abstract actions using concepts in the ontology. By using SPARQL queries to search against the knowledge base, the policy wizard can make use of the following information:

- the actuator classes available
- the properties of each actuator class
- the individuals in an actuator class that satisfy certain conditions over properties
- the operations supported by an actuator
- the parameters used by a given action.

To specify the actuator required, the user first selects a specific actuator class and then specifies conditions on properties of that class. For actions, the user chooses from the list supported by that actuator. Similarly, parameters are selected from those applicable to an action.

The built-in OSGi service discovery mechanism uses exact type matching. The semantic discovery module described here can find actuators based on subtype-supertype relations. Thus the search result for individuals of the *Light* class will also include those of the *DimmableLight* class.

By making use of the ontology, policy creation becomes easier because users can select alternatives rather than input them manually. Policy editing also uses familiar concepts such as 'living room light' rather than unfamiliar ones such as an X10 or UPnP address. Since the actuator can readily be extended with new definitions, the ontology-based specification of policy actions makes the approach more extensible.

5 Related Work

There have some efforts towards rule-based home care systems. [1] proposes a framework to integrate smart home technology with current care practices, focusing on temporal reasoning and spatial reasoning. [10] discusses a three-tier general architecture to support end-user programming of home care systems. Both work do not address actuator integration and discovery. The Gator [6] platform treats sensors and actuators as service objects, providing development environment to programmers, unlike our approach which is designed for the less technically minded. In addition, the Gator work does not consider dynamic aspects of the home care environment.

Semantic web technologies have been applied in pervasive computing environments to achieve interoperability among heterogeneous systems. In particular, ontologies have been used to model context and reason in pervasive computing environments [7, 5, 8]. [11] presents a user interface level context model for assistive living. However, its focus is on context modelling, not on actuator part.

6 Conclusion and Future Work

A framework has been presented for actuator discovery and invocation in home care systems. By making use of an ontology to model the services and operations of actuators, policy actions are made protocol-independent and are not affected by changes in home network configuration due to the evolution of home care systems.

Future work will extend the implementation to look at the following issues:

- Tools will be created to register devices as individuals in the knowledge base. Currently, adding/removing devices requires manipulation of OWL documents. For actuators with no associated service discovery mechanism, a simple solution would be a graphical tool for registering actuators manually. However, a promising approach could be using the smart-plug concept [9] to automatically register the functionality of actuators.
- The existing context ontology will be integrated with the actuator ontology, so that the user can specify both the situations and corresponding actions abstractly. The framework would automatically take care of mapping and execution. This would hide from users the uninteresting low-level configuration details of sensors and actuators. Evaluation of usability and acceptance of this approach will follow.

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Towards an Affective Aware Home

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Abstract. The nowadays smart homes run predefined rules, but the user's desired behaviour for a smart home varies, as his/her needs change over time. To edit the initial rules is a difficult task for a usual user. We propose a control mechanism that allows the system to learn the new behaviour preferences without editing the rules, but responding emotionally to the system's decisions. In order to capture the emotion reaction we use FaceReader, a tool for facial analyses, adapting it to read three valence levels that work as positive, negative or neutral feedback. The results in training a MLP neural network to learn the preferred behaviour from the user's emotional reaction are discussed. Ontology is used in order to describe the context.

Keywords: Smart Home, Affective Computing, Context Awareness, Ontology, Neural Networks.

1 Introduction

Editing the smart homes rules is difficult for the user because of the complexity that comes with the use of different sensors and actuator driving to a large number of combinations for the rules to include [1][2]. Moreover in [2] the authors notice that "rule-based reasoning is not flexible and can not adapt to changing circumstances".

Speech or motor impaired find difficult to give vocal or physical commands in order to control the behaviour of a smart home but they may facially display short time affective responses (emotions) that could be used as feedback. Taking as reference the normal neutral state, a positive emotion will mean approval and a negative emotion will mean disapproval of the system's decision, if expressed immediately after it.

Scenario. Maria is an old and speech impaired person. She is invited to her friend Laura that has a smart home. As Maria is a welcomed guess, the system will authorize her to personalize its behaviour. One of the home rule closes the blinds when the outside light has the same intensity as inside. Maria likes to look outside the window and so, when the first decision of the system to close the blinds is triggered (at sunset, for instance), she will display immediately (in the next minute) a negative emotion (i.e. anger) showing her disapproval. The smart home will learn (after repeating it a few time, if needed) the new Maria's preference.

Technical Issues. We have in mind the following questions to answer to:

1. How should we represent the Affective Aware Home's knowledge?

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1.1. How should we represent the context (including user data)?
1.2. How should we represent the preferences?

2. How are the user 's behaviour preferences discovered?

2.1. How do we get and interpret the emotionally response?
2.2. How does the preferred behaviour learning mechanism work?

Approach. We propose a control mechanism that allows the system to learn the new behaviour preferences without editing the rules, but responding emotionally to the system's decisions. In order to capture the emotion reaction we use FaceReader, a tool for facial analyses, adapting it to read three valence levels that work as positive, negative or neutral feedback. The results in training a MLP neural network to learn the preferred behaviour from the user's emotional reaction are discussed. Ontology is used in order to describe the context.

Paper outline. The rest of the paper is organized as follows. In section 2 we overview the existing solution regarding aforementioned questions. Then in section 3 we present the principle of the affective control loop mechanism. The implementation details of the Affective Aware Home are explained in section 4. In the next section the results in training a MLP neural network to learn the preferred behaviour from the user's emotional reaction are discussed. In the last section we conclude out work and present the future work.

2 Related Work

The use ontology in context modelling because it is independent from any programming language, supports formal representation of the context [3][4], allows for knowledge distribution and reuse, logical context reasoning (consistency check, subsumption reasoning, implicit knowledge inference) [5], has expressing power (i.e. OWL has cardinality constraints), hierarchical organization, use standards for efficient reasoning, abstract programming and interoperability [6]. By using reasoning mechanisms the context can be augmented, enriched and synthesized [7]. Moreover it solves heterogeneity, ambiguity, quality and validity of the context data [8].

The user data is usually considered as a part of the context and can also be ontologically modelled [9], including details on her/his affective states [10].

In [11] the authors review the existing context related preference representation and propose a scored based solution. They assign a score to each preference possibility, consisting in a real value in the [0, 1] interval or a predefined value (veto, indifferent, mandatory, error situation). If a context *C*, and an associated variable set *v* are present, the score will be the function *score(p.s,C,v)*, where *p.s* is the scoring expression, otherwise the score is indifferent. In this model the context elements are considered distinct, without any relation between them.

An ontological representation of the preferences is presented in [12]. It models ontologically the relations between the context elements and the preferences. The *Preferences* class has relations with all the main classes (*Time*, *Agent*, *Location*, *Activity*). The preference can be positive or negative indicating an appropriate or inappropriate choice for a resource, environment or operation. This model uses a probability to set the preference priority, but has only two values to express the relation between the context and the service (desired behaviour).

Another solution [13] uses Bayes RN-Meta-networks, organized in multi-layers. It is the only one we found to support online preference discovery mechanism in context awareness. The mechanism consists in updating the preference model for each user if the system's decision was disproved by at least one user. The preference model update is done by calculation the distribution probability for each user and then propagating the values to the next meta-network layers. Its main issue is that the prior probabilities need to be initially calculated by a human that is difficult for a large number of context elements. The main advantage of this model is that it supports online preference update.

In the article [14] the author presents an associative network between context and application. Each context element could be associated with all N applications for a user. The association relation was modelled by a variable weight *w* that indicated the connexion strength between the context element and the application, thus given the weight matrix and a certain context, one may predict the application a user will chose. Extending this idea, the weights could store the user's preferences, but still this solution lacks the advantages of ontological modelling.

The neural networks are used in [15] to describe weighted relations between the context elements (responding to: who, where, when, how) and the context elements (responding to how), the services and service parameters. They use MLPs (Multi Layer Perceptrons) with one hidden layer. This solution allows modifying the relations' weights, but the authors explore only the offline neural network training and do not use ontologies in context modelling.

Table 1. A comparison between different preference representation and update solutions

Solution	Ontological Context	Context-service relation	Online update
CtxPrefScore'06 [11]	-	score ([0, 1])	-
OWLPref'05 [12]	+	ontological(appropriate/not)	-
Bayes Meta-Net'06 [13]	-	probabilistic	++
NNAssoc'05 [14]	-	association network weights	-
UPM'05 [15]	-	MLP weights	+

We may notice in Table 1 that only one solution adopted an ontological context modeling, has only two values to express the relation between the context and the desired behaviour. There are different approaches for context-service (behaviour) relation which allow for a more or less fine grained expression of the preferences. In the last column, we notice that even if the MLP solution [15] supports weight update based on a back propagation algorithm it does not explore the online training from the user's feedback. The Bayes Meta Network solution [13] is the nearest to meet our online updatable preferences objective, but in this case they do not use ontologies and need a prior probabilities calculation.

Regarding the use of emotional response for learning the desired behaviour, the article [16] presents a reinforcement learning mechanism where a social robot learns from rewards and punishments expressed by positive (happy) and negative (fear) emotions. A reinforcement learning mechanism implies to give feedback for a set of tasks, but our objective is to have a simpler loop with immediate response. We also searched for a more general emotion valence assessment tool, explained in detail in section 4.3 where we justify the choice for the FaceReader[17].

3 The Principle of Affective Control Loop Mechanism

We made the following decisions for representing the Affective Aware Home's knowledge:

1. To use ontology for context and service representation
2. To represent the relation context-service, the preferred behaviour as weights, stored in the ontology
3. The preference update will be according to the user's affective reaction (emotions) to the system's decisions

In principle we consider the context *C*, composed by context elements in relation with each other, a service vector *S*, and a weight vector *w*, that records the preferred behaviour, that is the service to choose when the context *C* is present and a current affective state Ψ of the user *U*.

Preference representation. We argue that storing the preference in neural network weights is better then in Bayes RN Meta-networks like in [13] because:

1. The neural network allows initial training by an example training set, comparing to a mandatory prior probability calculations, simplifying the work at this stage.
2. If rules or Bayesian approach would be used a full description of the behaviour should be given (all combinations of context values and desired behaviour), a neural network can run with a few training examples if any, due to its generalization capability, and adjust online.
3. The neural network have the ability to generalize from a given set of examples.

Representing the preferences in ontology is motivated by:

1. The ontology supports the distribution and reuse of the once learned preference in other applications with the same context elements and services or similar (when increasing or decreasing one or more context elements or services)
2. The neural network is to become dynamically reconfigurable (we may change its parameters on runtime: the number of hidden layers, neurons on each layer, activation function type, learning rate for each layer neurons)

The actual part that the ontology that contains the representation of the neural network is beyond the purpose of this article, as in this first implementation we saved the neural network parameters values in a file.

The Affective Control Loop Mechanism. We propose to replace the rule based decision mechanism with a neural network that learns from the user's affective feedback the new preferred behaviour in order to respond to the user's new needs.

In order to estimate the current affective state we should use a software tool that analyses a person's facial features and asses the current basic emotion.

The mechanism works as explained below (see Fig.1):

1. At t_0 the system will choose a service for the present context by feeding forward in the randomly or prior trained (with values from that user's behaviour history in similar conditions) neural network.

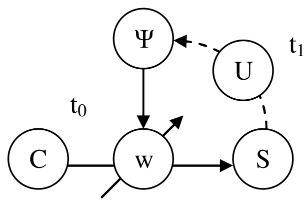

Fig. 1. The principle of preference update based on the user's affective response

2. This decision for a service *s* at t_0 will determine a user reaction in the next time interval t_1. From this reaction, we are interested only in the valence of the emotion: positive (meaning acceptance) or negative (denial).

3. The acceptance or denial will determine the adequate weight *w* modification. Then the cycle repeats from 1. This way the system adapts itself in successive steps.

4 The Affective Aware Home Implementation

We developed and tested an agent based architecture sharing a two layered ontology similar to the one presented in [4]. We used the Phidgets [18] sensors, RFID and motors platforms to read the room and outside light, to identify the user and to open/close the blinds. As a detailed description of the system is beyond the scope of this paper, we will focus on the parts that implement the affective awareness.

The Affective Knowledge Representation. We added in the context ontology the concept State as in [10], but, as we were interested by the valence representation for the current state, we defined the subclass CurrentState and for it the valence property with three possible values (positive, negative and neutral) as depicted in Fig.2:

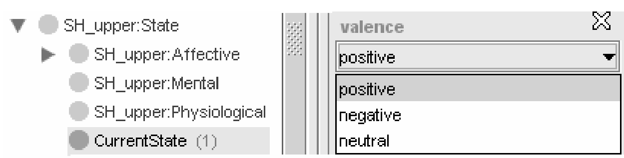

Fig. 2. Fragment from the *SH_lower* ontology illustrating a *CurrentState* individual (*left*) and its valence datatype property with the three possible values (*right*)

Modelling Preferences in a MLP Neural Network. At this stage we implemented our multilayer perceptron (MLP) using a public Java neural network API [19] that saves the network parameters in a file.

The entrance of the MLP had two inputs, the room light (LightSensor1) and the outside light (LightSensor0), with three possible values (low, medium and high) updated into the ontology by the sensor agent:

```
light_indoor=sensorMap.getSensorById("LightSensor1").getS
ensorValue();
```

There is just one output of the neural network, the blinds status (on/off) that has to be set up in the ontology once a decision is taken:

```
deviceMap.setDeviceStatus("Blind_2","ON");
```

The initial training set is generated by using a predefined rule for test purposes only: each time outside is brighter then inside, the blinds will open, otherwise they will be closed, a total of 9 input combinations, with normalized input and output values (-0.5 for low, 0.0 for medium, 0.5 for high; -0.5 for closed, 0.5 for open). In a real case, historical data could be used (input, desired output pairs) for this training.

After repeating several simulations the optimum MLP parameter configuration was 6 neurons in the hidden layer and 50000 epochs, or an equivalent of 0.05 training error rate.

We may compare this with the equivalent Bayes RN Meta-networks [20] solution where we have an important increase of prior probabilities with the number of inputs. In our scenario we would have to complete $3^2*2^1=18$ combinations, but adding a binary value input (authorized/not authorized user) the number of prior probabilities would double: 36. So, an exponential grows. Moreover the presence of two users demands for one more layer, resulting that for n users n+1 Bayesian layers are needed. As a consequence 3*36 = 108 values need to be computed.

The complexity of the Bayes RN Meta-networks [18] is:

$$O(N*p*q^{\alpha`}+q^{\alpha*N*p}) \tag{1}$$

Where *N* is the number of users, *p* is the user's probability to be in a certain location, *q* the number of service values or possible actions, α is a value proportional with the number of context elements multiplied by the possible values for that element. For the given example the complexity would be $O\ (1*1*2^6+2^{6*1*1})$ =O (128).

In the neural network case we reduce the complexity to:

$$O(e*q). \tag{2}$$

Where *e* is the number of context elements, q the number of service values or possible actions, so we have O (2*2) =O (4). That reduces the complexity 32 times.

Adapting the FaceReader. In order to know the affective reaction we used the FaceReader [17] software that analyse a person's facial features and asses the current basic emotion. We improved the current state valence calculation allowing for three levels (positive, negative, neutral) estimation by analysing the FaceReader's outputs in time after interpolating to solve the missing samples issue and empirically establishing particular thresholds between the levels for one user only: maximum instantaneous values for happy>=0.4, angry>=0.74, disgust>=0.65 and mean values for one minute (5 samples, one each 200 milliseconds) happy>=0.47, angry>=0.78, disgust>=0.82.

5 Results and Discussions

We ran 100 simulations for two inputs (outside light, room light) with three levels (low, medium, high) and one output (on/off blinds) and varying the neuron number in the hidden layer (1-10) and the number of training examples (1-9) to answer to what is the minimum number of examples needed to relearn the new preference, after an initial behaviour training. The best configuration was 6 neurons in the hidden layer, demanding for a minimum of 3 examples out of 9 possibilities to overlap 80% of correct behaviour for a new behaviour, increasing to 90% after 6 examples. The duration of the retraining is 780 milliseconds, less then 1 second the time we considered a person needs to express an emotion.

We had pilot experiments with the real setup in our research lab (sensor platform, ontology, blind motor, a web camera capturing the user's face for the FaceReader to assess the emotions) for one person, in which the prior trained neural network replaced the 9 behaviour rule set. In almost all test cases the trained rule was successfully replaced. We managed to have one successful retraining with the new preferred behaviour with just 3 examples, but we should do some more adjustments to the system to work fine: increase the number of random training examples to 6, reduce the time window for expressing the emotions and increasing the valence accuracy.

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6 Conclusions and Future Work

We proposed and tested a new behaviour control mechanism for smart homes, based on the user's affective reactions to the system's decisions. This allows preference discovery, storage and use for responding to ever changing user needs. At this stage the preferences are stored as neural network weights in a file, but we envision storing them in an ontological representation.

In order to know the affective reaction we used the FaceReader software that analyse a person's facial features and asses the current basic emotion. We improved the current state valence calculation allowing for three levels estimation by analysing the FaceReader's outputs in time and empirically establishing thresholds between the levels.

The next work should answer to the following question: how does the number of user given training examples for preference learning evolve once we increase the number of context elements.

We are also preparing a method to determine more accurately the valence (nine levels) and thus allowing neural network learning rate variation in accordance with the user's level of acceptance or denial for the Affective Aware Home's decision.

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Global System for Localization and Guidance of Dependant People: Indoor and Outdoor Technologies Integration

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Abstract. This paper deals with the problem of personal localization and guidance in indoor environments. The authors analyze different technologies which can be applied to this task. The goal is to provide users with the most accurate and reliable technology depending on users' profile. Indoor location technologies are analyzed and compared from different point of views. Relevant parameters which drive the overall system performance are highlighted. In particular, the indoor technologies studied are Bluetooth, WiFi, RFID, UWB and ultrasounds. With the aim to cover outdoor environments authors analyze technologies such as WiMAX and GPS. Finally, the indoor location system will be integrated with a GPS based outdoor localization system to provide global coverage. Based on this goal, integration issues are described and analyzed. All these investigations are within the framework of the project ELISA- Intelligent Location Environment for Assisted Services- www.elisapse.es.

1 Introduction

The heyday of location systems is driven by the growing demand of location-based services applications, such as objects or goods location or person location. From the point of view of applications that provide personal services, there is an increasing demand of that kind of location based services with very different purposes: professional, personal, recreational, safety, etc. Care services also are becoming assisted by location information.

When we restrict ourselves to a collective of citizens who have special needs, either sensorial, motor or cognitive (dependant, disabled and elderly people), location based

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services can provide final users with a high level of autonomy and safety through the assistance these services can supply. Thus, they promote their social inclusion and the ability to avoid physical obstacles by appropriate guidance. In general terms, we are used to location based services for outdoor environment, based mainly on GPS technology. However, GPS's usage is not appropriate inside buildings because of the lack of coverage. This is due to the satellite signals absorption in building structure elements.

In order to provide a proper location management platform, the development of a location management system is required. Besides, it provides roaming facilities to the mobile devices linked to the system.

ELISA stands for Intelligent Location Environment for Assistive Services (*Entorno de Localización Inteligente para Servicios Asistidos* in Spanish). This paper is mainly aimed to show the theoretical and technological bases and challenges of ELISA project. ELISA project is developed by a consortium of 18 Spanish partners, composed of companies, research centres and universities which collaborate to deploy an integral system for location and guidance of dependant people aimed to the social inclusion of people with different disabilities.

The structure of this paper is as follows. Section 2 is devoted to the most promising indoor location technologies and new proposals for outdoor location, highlighting their advantages, disadvantages and location accuracy. Indoor location technologies integration is described in section 3. In section 4 different services provided for ELISA are described, both in indoors and outdoors environments. Finally, section 5 describes the most relevant conclusions inferred from the work.

2 Indoor Location Technologies

The critical issue in the development of an integral people location system is the technology to be used inside buildings. Although in outdoor environments GPS is the main option, new choices like WIMAX are under study. There are several options in technologies used to provide these capabilities to the system. It is necessary to analyze their suitability for that purpose based on their accuracy, range, reliability, size (portability), power consumption and deployment cost.

2.1 Bluetooth

Bluetooth is a short range wireless technology that fulfills IEEE 802.15 standard and works in the 2,4 to 2,48 GHz band. It allows creating personal area networks for data and voice communication. There are three different kinds of devices according to their transmission power. Data transfer rates fluctuate from 1 to 3 Mbps. The Bluetooth device range varies in function of device types between 1 and 100 meters. Power consumption in different device classes is not very high, but a key issue in terms of autonomy for portable devices development.

The key advantages provided by Bluetooth technology are the omnidirectional transmission that means a whole coverage, the high number of devices with Bluetooth technology and its low prize. Other advantages are the low consumption and the security provided in different layers.

As drawbacks, it can be mention the possible interference with other technologies, the required analysis of the scenario, the possible saturation due to number of devices and the delay for real time applications cause by the device tracking process.

2.2 WiFi

WiFi Technology is widely used by positioning and location systems. It uses algorithms to obtain the position from different access points (AP) to the network and general parameters like[1]RSSI or[2]TDOA. It's possible to know the relative service's user position depending on the analysis made by a single subject. It could work as a central node (outdoor location) or inside the mobile device (own location), from different access points of the surrounding area. Table 1 highlights the main characteristics and differences between the different versions of the standard 802.11.

Table 1. Standard 802.11

Technology	Modulation	Data Rate (Mbps)	Transmitted power (mW)	Range (m)	Frequency (GHz)
802.11a	OFDM	54	40-800	20	5
802.11b	DSS	11	200	100	2,4
802.11g	DSS/ OFDM	54	65	50	2,4
802.11n	OFDM	540	25-50	50	4-5

The advantages WIFI technology presents over other systems are the open working bandwidth, the possibility to realize location by the device and send data easily and finally the user-friendly network configuration scalability. On the other hand, WIFI technology has some drawbacks as the higher devices prize, the sensitive to interference and the higher power consumption than other technologies.

2.3 RFID (Radio Frequency IDentification)

RFID systems allow storing and recovering information loaded in known devices with nametags by radiofrequency. In an RFID design some tag reading issues must be taken into consideration: distance, measurement angle and number of simultaneous tags. RFID-based location systems are classified into two main groups according to their operational procedures. The first one is based on static tags location by a user with a RF-reading unit. In the second one, a fixed reading unit is able to show the tag location. Several location models are found:

- Users carry a tag which is located when entering a RFID-reading area. This model requires a reader infrastructure and if sending the location information to the user is wanted, an additional unit is needed. Besides, cost becomes a limitation.
- Tag tracking, while a user carries the RFID reader. The system returns the tag location. If the tag is fixed and we know its location, we can calculate the location. The infrastructure required supposed a high cost of the reading devices.

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[1] RSSI, Received Signal Strength Indication.
[2] TDOA, Time- Difference of Arrival.

- User carries a RFID reader in a RFID tagged zone. In order to allow the reader device to calculate its position, taking into account the data retrieved from the tags, a previous mapping of the RFID tags is required. Its main inconvenient is the prize and size of the reader device.

2.4 Ultrawideband (UWB)

It is based in RF signals transmission, with an extensive bandwidth and a low work cycle. It can use different frequencies from 3.1 GHz to 10.6 GHz. Each radio channel has a bandwidth of over 500 MHz [4].

The use of UWB technology in location systems has the following advantages:

- Location and communication using the same system.
- Extended indoor propagation capacity due to penetration capacity of the waves.
- Extended bandwidth (resolutions up to centimetres).

On the other hand, this technology also presents the following disadvantages:

- Multipath propagation makes triangulation difficult.
- The environment must be modelled.
- Interferences with other wireless technologies depending on the work frequency.

2.5 Ultrasounds Based Systems

These systems use acoustic signals of frequencies up to 25 KHz. Due to the acoustic nature of the signals, ultrasounds-based systems do not interference with other communication systems. The measurement of the[3]TOA o[4]TOF of a signal that is propagated from a transmitter to a receiver provides information about its relative distance. Due to the low speed of ultrasound propagation, the TOF parameter is measured with high precision. Furthermore, 3D positioning of the moving object can be inferred using triangulation. An ultrasound system is composed by one or more ultrasound signal detectors, and one or more ultrasound tags. An ultrasound tag is transmitting its identifier periodically to the system using ultrasonic waves. The nearest ultrasound detector receives the signal, analyzes it, and communicates it to a control.

2.6 WIMAX

WiMAX is a long range wireless technology suitable for indoor as well as outdoor positioning applications, due to its[5]NLOS coverage feature, and its moving-peer support feature (up to 100 km/h). WiMAX typically operates at 2.5, 3.5 and 5.4 GHz, using OFDM modulation, and providing several settings of used bandwidth and medium access control, these last specially related to security and[6]QoS options. The positioning may be done: at WiMAX cell level where user device is found because of the base station position; at WiMAX triangulation level where the user device position is

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[3] TOA, Time of Arrival
[4] TOF, Time of Flight
[5] NLOS, Non Line Of Sight
[6] QoS, Quality of Service

calculated from signal level measurements (RSSI, CNIR); and at mixed level with the help of other technologies.

3 Technologies Integration for Indoor Environments

Once the most relevant available indoor location technologies have been analyzed, the next step is their integration in a global system. This system provides several location based services, including both indoor and outdoor technologies.

All indoor location technologies can be combine to increase the accuracy of the locations, but we can conclude that, speaking in accuracy terms, all the technologies provide satisfactory results, with errors ranging from tens of centimetres to few meters, and this fact that is aligned with the user requirements.

These are some key requirements for outdoor scenarios:

- Availability of a communications network: Outdoor deployments do not require a sensor network as indoor environments; usually some network is already available (GPS System or GSM/GPRS). The calculation of the position is made in the mobile device. It is required that the scenario have, at least in certain areas, any of the following networks: GSM, GPS, UMTS or WiFi.
- Feasibility of including new communications networks such as WIMAX.
- Points of interest: A group of fixed points of interest, which position will be constant and stored on the system.
- Availability of a medium-high level of accessibility: the scenario must be accessible in order to grant mobility, avoiding architectural barriers.

The integration and coordination of technologies is achieved using an appropriate location management platform. This has been a key point in the development. This platform is aimed to determine the accuracy of the location provided by different technologies. The platform combines the data provided by various location systems and calculates the position with the greatest possible accuracy. Besides, the platform is able to determine and discard wrong location data.

The other key point is related to the itinerancy of users through different networks. A user following his way goes along outdoor areas, which will be covered by GPS technology (network), and indoor areas, which can be covered using various technologies. The location management platform must manage appropriately the roaming between different areas, providing proper tracking of the user continuously. The availability of the tracks with previous positions is relevant to the roaming control of the user. Appropriate algorithms provide this functionality to the system.

4 Services

ELISA provides multiple services focused on simplifying daily live to dependant people, elderly people or people with any disabilities, and professionals involved in their cares. ELISA will be deployed in a special centre for dependant people where they have a degree of independency according to their level of disability. These users have been a central part of ELISA from the beginning of the project. The services will be location based, will be provided both in indoors and outdoors environments, and will be personalized in function on the users profiles.

4.1 Indoor Services

The Fundación Matia was selected as the mounting place for indoor services due to the wide diversity of users. The users were divided upon three categories: relative, carer and patient. This last category was also divided into three possible profiles for the pilot test: young, elderly and patient highly dependent on carers. For the pilot test, five services are going to be developed:

Access control. This service will prevent unauthorized personnel (patients) from entering restricted areas or leaving the installation. When the patient enters any restricted area, the system will activate the automatic protection for this area and the carers responsible of the patient will receive an advice in his/her PDA.

Equipment location. This service will allow the carers to locate free wheelchairs. All wheelchairs not assigned to a private user will have a pressure sensor based on ZigBee to determine if it is being used and a RFID TAG to locate them within the center. Carers will use their PDA to choose which wheelchair they want to locate. A map of the center showing their position and the position of the wheelchair selected will be shown.

People search and location. The main aim of this service is to provide a support tool to carers. Through this service carers are allowed to locate any patient within the center. There are three different ways to search a patient; by ID of the patient, by profile and by area.

Guiding service. This service will guide the user from their current position to the desired one. After the user has selected where to go, the service will provide a map of the centre with his position and the destination and the route according to his profile.

Alarm. Any patient having a PDA will be able to inform the carers by an alarm in the career PDA that they need some help. Apart from this communication, the carer can have a map of the centre with his position and the location of the user who activated the service.

4.2 Outdoor Services

Outdoor services will be based on GPS technology. The area surrounding Fundación Matia has been selected as the test area. Thus, users will perceive ELISA as a unique system, even if indoor and outdoor services are based on different technologies. Test users have been divided in two categories: carer and patient. The pilot test will provide six different outside services:

Generate user content. Users will be able to create their own content with their mobile devices, annotating, uploading and sharing it with the community. If the mobile device has GPS or if the system is able to locate the user, the location information will be automatically included. Finally, the contents are sent to the server using one of the available communication networks (GPRS, 3G, Wifi).

Alarm. This service is equivalent to the provided at indoor locations. The only difference is that the carer will receive a map of the outdoor environment instead of one of the building.

Personalized routes. The objective of this service is to create a route allowing users to visit the destination points they want. The route will take into account possible disabilities users could have. Besides, routes will use public transportation when it is adapted to user's special needs.

Public transportation. This service focuses on helping users to move on public transportation. It is directed to users from Fundacion Matia and any disabled people in general. Once users have selected the departure and arrival stops, the system will give them information about the next public transport adapted to user's needs.

Navigation. This service allows users to explore their environment. While they are moving around with their mobile device, users receive information about interesting locations. These locations can be related to:

- Locations important for the mobility of users: stairs, traffic lights …
- Locations needing special explanations to use: advanced automatic machines …
- Locations that have been interesting for other users
- Locations with a cultural and historical interest: sculptures, special buildings …

People location. This service is focused only on helping carers. A carer has to choose, among users he has permissions to locate, a patient. The system will look for the last known position of the user and will show them on a map.

5 Conclusions

This paper shows the work bases for the development of an integral people location and guidance system for both indoor and outdoor environments, taking into account several key issues such as decision criteria.

Due to the efficient location solutions already deployed in outdoor environments (such as GPS), research was focused on indoor location environments and their integration with outdoor scenarios location technologies. Together with these, upcoming technologies suitable for the outdoor location solutions such as WIMAX were studied. Depending on system requirements, as inferred from Table 2, the most appropriate technology will be selected according to each particular situation.

Depending on the covered area and the accuracy requirements, different technologies should be used. Additional considerations must be taken into account when the service is aimed to people usage: in this case accuracy is not only required but reliability and availability. Authors have highlighted along this paper the main characteristics of the locations technologies (including devices requirements), highlighting the accuracy and deployment feasibility as key decision points of the technology or technologies choice for the system development.

Coordination of various technologies provides a remarkable increment both in location accuracy and system reliability. Appropriate algorithms are being developed to combine position measurement from different technologies (when possible) and management strategies are also aimed to preserve portable devices battery power.

A management platform has been developed in order to coordinate indoor and outdoor locations to provide global coverage. The analysis of available networks can reduce the deployment of the system and it saves a lot of time in the implantation task. The deployment of such a system providing both location based services and guidance for disabled and the elderly will improve users' quality of life, by

Table 2. Different location technologies comparison

Classification \Technologies	Bluetooth	WiFi	RFID	Ultrasounds	UWB	WIMAX
Tags usage	No	Yes	Yes	Yes	Yes	Yes (CPE)
Environment	Indoor	Mixed	Indoor	Indoor	Indoor	Outdoor/Indoor
Kind of measure variable	RSSI	RSSI	RSSI	TOA,TDOA	AOA, TDOA	Cell ID/RSSI-CINR
Location technique	Trilateration	Trilateration /Power maps	Trilateration, Fingerprint	Spherical Multilateration	Trilateration	Cell/ Multi-lateration
Synchronism	Si	Si	No	Si	Si	Si
Location coordinate	Node relative	Node relative	Node relative	Node relative	Node relative	Absolute/Node relative
Granularity	3D	3D	3D	3D	3D	3D
Accuracy	1- 10 m	5-10 m	1 m	1 cm	15 cm	5-30km/5-50m
Additional HW deployment	No	No	Yes	Yes	No	No
Node mobility	Nodes: permanent: moving target	Nodes: permanent: moving target	Nodes: permanent moving target	Nodes: permanent, moving target	Nodes: permanent, moving target	Nodes: perma-nent / portables, moving target
Position calculation	Centralized	Centralized	Centralized, distributed	Mobile node or centralized	Centralized	Centralized
Kinds of emission	RF	RF	RF	Ultrasounds	RF	RF

eliminating/avoiding barriers and increasing their autonomy. Additionally, this system provides complementary services to the health, care and medical centre.

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An Architecture to Combine Context Awareness and Body Sensor Networks for Health Care Applications

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Abstract. Information derived from wearable sensors, such as illness/fall alarms, can be enhanced with context information to provide advanced health care and assisted living applications. In this paper we describe an architecture that combines sensor and context data into a telecommunication service to detect emergency situations and generate alarm calls according to user's preferences and contacts geographic proximity.

Keywords: Body Sensor Network, Wireless Sensor Network, SPINE, Context Awareness Platform, Context Broker, ContextML, Context Query Language, health care monitoring.

1 Introduction

The progress of the body sensor networks (BSNs) technology and the development of context aware telecommunication platforms open great opportunities in healthcare systems. Pervasive applications may assist elderly and disabled by providing home assistance and emergency communication, therefore reducing the cost and inconvenience of visits to doctors and emergency rooms.

BSNs for health care applications consist of sensors that measure physiological and motion parameters of the patient or the elderly, and algorithms for the interpretation of the sensor data In addition to the data derived from the body sensors, context information about the user or the environment can play a very important role and enhance health care services. For example users' location can be used to detect the closest medical center, environment temperature can influence physiological parameters, etc.

This paper presents a platform that integrates BSN data, environment and user's context information and allows to provide a health care telecommunication service to detect emergency situations. In the proposed platform real-time BSN data acquisition and analysis is performed within the SPINE (Signal Processing in Node Environment) framework. SPINE is an open source software framework for the design and management of BSN applications; it provides APIs and libraries of protocols, analysis and the classification of sensor data, utilities and data processing functions. Other design

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frameworks that have been proposed for BSNs are *Titan* [5] and *CodeBlue* [6]. Titan (Tiny Task Network) is a task oriented framework that defines the application as a set of tasks distributed on the sensor network. This framework has been used on Sensor-Button [11] devices for activity recognition applications based on accelerometer data. CodeBlue is a framework designed to provide routing, naming, discovery and security for wireless medical sensors but does not have extensive on node signal processing capabilities like SPINE.

Context information acquisition, aggregation and elaboration are performed by the Telecom Italia Lab's Context Awareness Platform (CAP). CAP allows easy integration of context information into the existing infrastructure of a telecommunications service provider, offering the unique opportunity to deliver context-aware services to a wide range of users.

Several frameworks for context acquisition and processing have also been proposed in literature [7][8][9]. In our application scenario, we are interested in a context processing platform that enables applications to receive asynchronously context updates, expressing their context needs using a platform independent context query language. Applications should ignore how context is gathered, reasoned and notified, obtaining complete separation between the application layer and the context acquisition/reasoning layers. In particular, context platforms that support a Query Language to access context have been proposed and analyzed in [2]. Compared to other solutions, the context processing and query language used by our system offer asynchronous context notification, high abstraction from underlying technologies, and complex context filtering features as required by our Fall-Illness Alarm application.

The paper describes how to integrate SPINE and CAP in the design of a health care application: "Fall-Illness Alarm". The purpose of "Fall-Illness Alarm" application is to increase the feeling of safety for elderly and disabled people and use context information to optimize and shorten emergency assistance. It is able to detect emergency situations (fall, illness) and generate alarm calls according to user's preferences, geographic proximity and available contacts.

2 "Fall-Illness Alarm" Application Scenario

The purpose of the "Fall-Illness Alarm" application is to increase the feeling of safety for elderly and disabled people and ensure that emergency assistance is provided in short time. This application allows detecting particular situations where a prompt reaction could help a person in case of emergency: it detects alarm conditions, knows her geographic location and makes the proper alarm calls according to customer preferences or geographic proximity and availability of customer's contacts.

The person being monitored should wear a BSN that allows to collect data and infer the person ACTIVITY through recognition algorithms. Activities that can be recognized are: STANDING, SITTING, WALKING, LYING and FALLING. The latter activity must be notified immediately. Besides the detection of movements, the BSN can also check physiological parameters and recognize when a person is ILL. The BSN periodically publishes those two parameters (ACTIVITY and ILLNESS) on the CAP, which stores and makes them available to applications . To achieve its task, the Fall-Illness Alarm" application subscribes itself to the CAP to receive notifications about changes on both ILLNESS and ACTIVITY parameters. As soon as one or both these conditions are true (ACTIVITY=FALL or ILLNESS=TRUE) a notification is sent by the CAP to the application, which triggers a logic to deal with the recognized situation.

The application allows to specify who should be informed first in case of emergency: each person is profiled in a centralized server, named Advanced User Profile, which contains the users' information like: personal contact information, address book of relatives/friends contacts, the assigned General Practitioner (GP)/doctor and the emergency contacts.

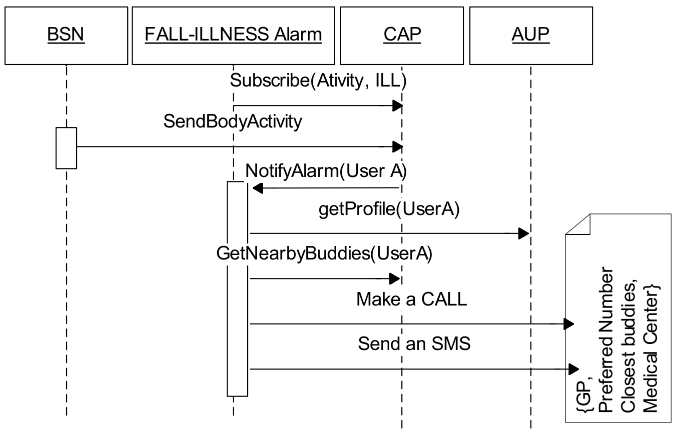

Fig. 1. Sequence diagram of the Fall-Illness Alarm application logic

The application logic changes depending on the detected situation.

In case of an *ILLNESS alarm*, the first operation is to obtain the GP number from the Advanced User Profile, call him by playing a synthesized "Illness emergency" message that provides the name of the person with the ILLNESS condition, his current location and the phone number of the nearest Medical Centre. At the end of the call, information is also delivered to the doctor through SMS. If the GP doesn't answer, the call is diverted to the closest Medical Center.

If a *FALL alarm* is detected, the application tries to call first the preferred emergency contact as configured in the user profile. A synthesized "Fall emergency" message will provide the name of the fallen person and his current location. If the contact doesn't answer, the application will detect which of the contacts (relatives or friends) from the address book is localized near the fallen person, according to the available context information. If none of the closest contacts is able to answer, the application will try to call the GP and, finally, the call will be redirected to the closest Medical Center. At the end of the call an SMS with the same information is sent to the selected contact.

If both the alarm conditions are detected at the same time, the application acts combining the previous described situations.

3 Architecture

The general architecture integrating the BSN and the CAP is described in Fig. 2. The BSN is connected as a context sensor to the CAP; detected ACTIVITY and ILLNESS conditions are provided to interested applications as context information. The following paragraphs describe the CAP and SPINE sub-components in more detail.

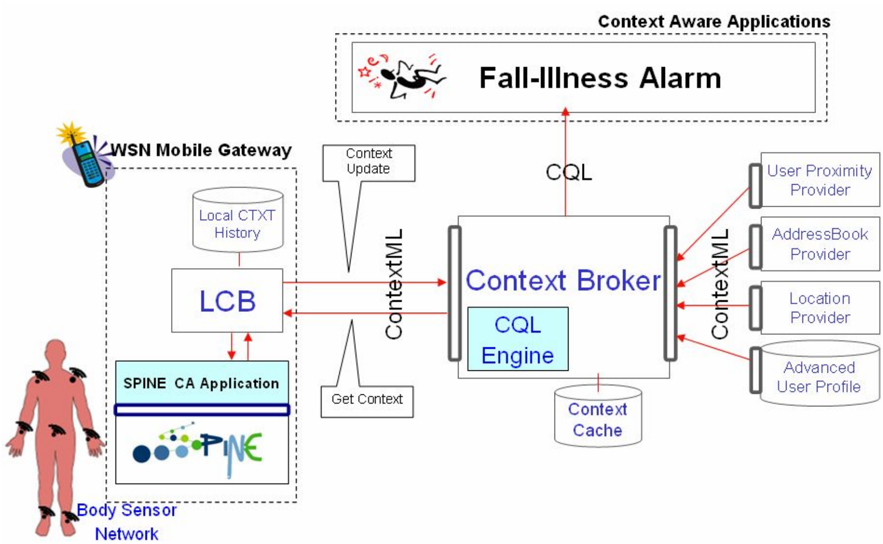

Fig. 2. Architecture integrating Body Sensor Network and Context Awareness Platform

3.1 Telecom Italia Lab Context Awareness Platform

Telecom Italia Lab's Context Awareness Platform (CAP) [1] supports context acquisition, aggregation and elaboration. In CAP a Context Broker (CB) receives context updates from devices, and stores them in a Context Cache until they are valid. For example, context data such as device GPS position, nearby Bluetooth devices, nearby WiFi access points and Fall / Illness status (as derived by SPINE from the BSN) are all asynchronously received from the device and cached.

The CB computes higher level context information with the help of Context Providers. An example is the *User Proximity Provider*, which is able to compute the relative proximity of two users by analyzing nearby Bluetooth and WiFi raw context information sent by their devices. The same raw context information is used by the *Location Provider* which, with the help of external geo-information services, can provide address and in-building positioning of the device.

CB also provides profile information and contacts' information by integrating the *Advanced User Profile* and *Address Book Provider* components.

In CAP all context information is structured using a common XML-based Context Mark-up Language (called *ContextML*), which provides context data as parameter/values pairs, enriched by meta-information such as source, entity, scope (or context "topic"), timestamp and validity.

To enable sophisticated access to context information, a *Context Query Language* (CQL) has been designed [2] to allow applications to structure their interest in context using a XML language. The query language offers both request-based and subscription-based queries and is used by the Fall-Illness Alarm application to subscribe to context changes on information provided by the SPINE Framework.
The *CQL-Engine* analyzes the CQL query and sets proper triggers to remember when and how to notify the application about changes in the requested context information.

To optimize context updating to the CB, a *Local Context Broker* (LCB) component is installed on the "Wireless Sensor Network (WSN) Mobile Gateway".
LCB is connected to SPINE through an adaptation layer and is responsible to structure in ContextML the data coming from SPINE and send it via HTTP protocol to the CB at specific intervals. The SPINE CA Application will also consume context information through LCB, which caches received data on a local memory, thus avoiding unneeded data transmissions to request context that is still valid.

3.2 Body Sensor Networks and the SPINE Framework

A Body Sensor Network (BSN) is a collection of tiny devices (nodes), equipped with a microcontroller, a transceiver and one or more sensors that wirelessly communicate data sampled by the sensors. BSN nodes are typically small in size and battery operated; hence, they can be easily worn or even embedded in clothes and accessories. BSN nodes placed on the user's body may be used to monitor his activities and his health condition depending on the sensors that are embedded on the nodes.

In the application scenario described in this paper, user's nodes are equipped with motion sensors, 3-axis accelerometers and 2-axis gyroscopes, and bio signal sensors for heart and respiration examination. While motion sensors are used to monitor user's activity and send an alarm notification when needed (e.g. fall detected), the other sensors are used to monitor user's health and notify diseases. BSN nodes on the body locally process sampled data and send the results of this computation to a collector device, called Coordinator, usually a mobile phone, that has the role to configure and manage the BSN as well as further process received data [3]. The BSN described in this paper has been implemented using the SPINE framework.

SPINE (Signal Processing In Node Environment) [4] (see Fig. 3) is a software framework for the design of signal processing intensive (SPI) applications in Body Sensor Networks. SPINE is composed of two modules, namely Server and Node side, which respectively contain the software code to run on the Coordinator and on the Sensor Nodes.

The Coordinator has the task to set up and manage the network as well as configure the nodes to send the needed information and to collect data coming from the sensor nodes. Coordinator devices may be mobile (e.g. PDAs, mobile phones) or fixed (e.g. access gateways, video phones) as far as they provide the wireless connectivity with the sensor nodes.

Sensor Nodes are worn by the user: their main task is to sample data coming from the embedded sensors, pre-process it and send the result back to the Coordinator depending on the existing configuration.

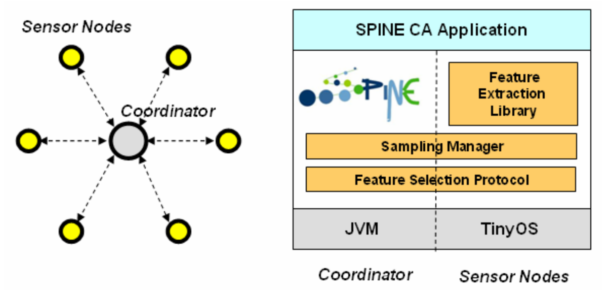

Fig. 3. SPINE framework software architercture

The SPINE CA Application has been developed using SPINE Java APIs to communicate with the BSN and then provide context information to the Local Context Broker as previously described. SPINE APIs allow the dynamic discovery the BSN functionalities (e.g. the sensors' type, the nodes' computation capabilities and more) and configure the BSN itself to report the needed information. In the sample application we described, BSN nodes are configured to send some features on the acceleration signal to then classify the action the person is doing and to report an alarm message whenever the person falls or its vital signs seem to be not normal.

Specifically, the SPINE CA Application manages BSNs composed of two sensor nodes with accelerometers to monitor person's activities and one sensor node equipped with biosensors to monitor the vital signs of the person (e.g. ECG and respiration rate).

The SPINE CA Application will then post the person's activity and alarms (BSN generated context information) to the LCB. On the other hand, the LCB can provide context information to the SPINE CA Application that can be then used to dynamically configure the BSN. For instance, if User Proximity context information shows that the caregiver is nearby the user, the BSN can be configured to stop monitoring the activities and the same nodes may be used for other purposes (e.g. rehabilitation exercises). The doctor can also remotely change settings on the BSN to better monitor the person's heart rate.

4 Evaluation

The SPINE CA Application has been implemented using as a K-Nearest Neighbor (K-NN) [12] classifier that takes as input from the motion nodes the significant features selected using the sequential forward floating selection (SFFS) [13] approach. In this example activated features are:

- Motion sensor on the waist: mean on the accelerometer (sampled at 40 Hz) axes xyz, min value and max value on the accelerometer axis x;
- Motion sensor on the leg: min value on the accelerometer (sampled at 40 Hz) axis x.

The performances of the solution have been evaluated in terms of classification accuracy and wireless channel usage [3]. The classification algorithm allows to recognize four different activities such as SITTING, LYING, STANDING and WALKING. The system has then been tested in a real deployment and the results of the experiments have shown a 97% classification accuracy. In terms of wireless channel usage, in the described application the feature selection mechanism implemented in the SPINE framework allows a channel bandwidth saving of almost 90% or more [3] if we compare with the raw data approach, typically used in BSN, where a data packet is sent to the coordinator for each value sampled on the sensor. Moreover, the motion node at the waist is configured to send an alarm whenever the total energy of the acceleration is above a certain threshold: the FALL ALARM will be sent through the LCB only when the alarm is received by the node and the classified action is LYING, to avoid the report of false alarms.

The biosensor node is configured to send alarms whenever vital signs are out of the normal range but can be runtime configured to send raw or processed data to better check the person's health. The biosensor board [10] has been recently integrated in the SPINE Framework and experimental tests of the application including biosensor nodes are currently in progress.

Data derived from the SPINE framework has been collected as context information by the CAP and notified to the Fall-Illness Alarm application. During our evaluation, the Fall-Illness Alarm application has correctly placed an alarm phone call to a contact near the location of the user in 92% of the tests (errors might occur when the transition to the lying position is too fast); in particular positioning of the user has proven to be accurate enough, always detecting the correct room.

The Fall-Illness Alarm application has also been described to some elderly patients to receive feedback. Patients have underlined the benefit of the application being integrated with their phone device and contact lists, without the need of any additional transmission device.

5 Conclusions and Future Work

The architecture combining the context-aware platform and body sensor networks based on the SPINE Framework that we have presented in this paper has the potential to support a new generation of health care and assisted living applications (e.g. "Fall-Illness Alarm") able to adapt to a wide variety of user needs depending on the user's context. As future work, the CAP will be further developed with features that ensure the privacy and security of health information. Furthermore new functionality should be added to "Fall-Illness Alarm" application in order to provide on demand information about user's illness status (or monitoring user's health) and physical activity.

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Multimodal Laser-Vision Approach for the Deictic Control of a Smart Wheelchair

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Abstract. This paper presents the design of the deictic functionalities for the navigation of a semi-autonomous powered wheelchair driven by a person with disability. Such functionalities, primarily based on a command by vision and a control by laser, offer an ergonomic mode of control to the user. The first functionality implemented is an automatic passing through narrow passages. The user must point the objective to be passed through, on an interface presenting an image of the environment. Then, the wheelchair moves in autonomous mode. Firstly, we describe the controlling mode for the wheelchair, the perception of the environment, the user interface and the means of path following. Then, we present and comment the results obtained during the experimental tests.

Keywords: Smart Wheelchair, Vision, Deictic Control, Laser Range Finder.

1 Introduction

At present, wheelchairs with manual or powered propulsion provide mobility to a great number of people with disability. However, much force is required to drive a traditional wheelchair, and a certain level of dexterity to drive a powered wheelchair, leaving the use of wheelchairs still difficult for a significant population of disabled people. An in-depth study clinicians and doctors [1], estimate them from 1.4 to 2.1 million people lying under this case in the United States. This highlights the utility of the studies undertaken since the mid-eighties on the development of smart wheelchairs. Their aim was to facilitate the control of a wheelchair. A state of the art was carried out in [2] presenting the various types of technologies, methods of instrumentation and control used, as well as the list of research projects carried out. The first systems consisted of a mobile platform equipped with a seat and sensors. They used technologies of autonomous mobile robotics for the types of sensors used (Ultrasounds, Infrareds or Vision) as well as for the movement algorithms (obstacle avoidance, wall following, etc). For example, Mister ED [3] and Vahm-1 [4] was composed of a robotic platform base equipped with ultrasound sensors. Many projects were developed thereafter, around commercial powered wheelchairs undergone through heavy instrumentation, and integrating a computer and a set of sensors. The advantage was having a system focusing basically on human and thus more adapted to him. For example, Navchair [5] is a prototype design originating from the Lancer™ model,

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equipped with an array of ultrasound sensors and a computer. Its movement algorithms are reactive, based on the histogram of obstacle densities.

We have developed a prototype, the Vahm-2, at our laboratory based on the PowerPush™ wheelchair equipped with autonomous and semi autonomous functionalities [6]. Many other prototypes were developed, which differ in the possibilities in control methods, the modes of navigation, the nature of environments considered and the data processing methods [7].

Some recent works aim at designing lighter structures providing specified smart functionalities and which are likely to adapt to all types of electric wheelchair. Thus the SWCS [8] proposes assistance in navigation through a system comprising of US, IR sensors and Bumper. Moreover, recent progress in terms of miniaturization and cost suggests certain types of sensors, such as laser range finder sensors or cameras, to be more adapted to these problems.

The objective of these wheelchairs is to allow autonomous movements to the user without depriving him of the possibility to intervene. To find a level of comfort between the wheelchair's autonomous control and the control of the user over the actions carried out by the wheelchair, one can ask: how as well as possible to employ human intelligence in this human - smart wheelchair association? [9] and [10].

The best way of letting the user command over the process is to consider his cognition during movements. More precisely, the actions should be oriented towards complementary control between the wheelchair and the user. That's why the choice, concerning the user interface and the user input mode on the wheelchair, are very important. The current input control mechanisms range from the standard joystick based control or switching sensors (pneumatic switch, pushbutton, etc), to more sophisticated input mechanisms such as treatment of the physiological signals (EOG), video analysis of the user (position of the face, eyes), or more recently, rests on the interfaces projected by video projectors and analyzed by camera [11]. On the matter, a promising approach is "the deictic" [12]. The concept of a deictic interface lies in proposing an outline of the environment to the user on which he points the localization that he wishes to reach. It has the advantage of being very intuitive and has already been considered in two projects, [13] on a mobile robot and [14] on a mobile platform.

We have developed our own deictic control for a powered wheelchair. In the following, the methodology adopted for a particular functionality, the passing through of narrow passage, is presented. Firstly, the means implemented to be able to control the wheelchair, the mode of perception of the environment and the deictic approach applied to our interface with the user are exposed. Next, we discuss the method of detection of the narrow passages in the environment, the generation of the trajectories and the mode of control of the wheelchair. Lastly, the experimental tests carried out, starting from this functionality, are described, three characteristic examples are detailed and the set of tests achieved are analysed. Thus the potentialities of this approach are emerged.

2 Methodology

Our problematical is to define a set of behaviours of the wheelchair, making it possible to drive it by means of a deictic command. Using a light structure made up of a computer, a laser range finder sensor and a camera, the idea is that the user should be able to control the wheelchair by simple and intuitive instructions such as: "I want to pass this door ", "I want to reach this point " or "I want to follow this wall". Thus, the user will have to provide (through an interface) two types of information to the system: the type of action to be carried out and the localization of the target in the environment. In this regard, our first conception is the functionality of automatic passing through a narrow passage. The image from the camera, fixed on the screen, is used as an input interface with the user where he indicates the passage to be reached. Measurements from the laser sensor are then used to determine the trajectory to follow. This first application enables to outline various possibilities of this “vision-laser” association.

2.1 Control Method of the Prototype

The Vahm-3 prototype developed at the laboratory is in fact, the instrumentation of the model of wheelchair Storm™ manufactured by Invacare. It is equipped with a computer, a laser range finder and a camera, (Fig. 1). This wheelchair is usually controlled by a joystick, while our objective is to control it through instructions sent by program.

One of the problems encountered in our approach is the impenetrability of existing technology which, moreover, varies according to wheelchair. Indeed, we have no knowledge of the way of generating the voltages from the joystick, of the communications protocol between the different elements of the wheelchair (for example the DX bus) and of the internal regulation of the vehicle. In order to bypass this problem and to return our developments adapted to all wheelchairs, we design our system by "simulation of the joystick", i.e. the trajectories will be expressed in a succession of joystick positions (defined by the angle and the amplitude) which will be converted into voltages sent to the motors. In this aim, we established a fuzzy logic module, which determines the voltages sent to the motor control according to the position of the joystick. It is based on qualitative considerations which reproduce the movements as close as possible to actual joystick control. The design of this module [15] can make our system easily adaptable to any commercial model of powered wheelchair.

Two types of control are thus possible: the usual manual mode by the joystick and the programmed mode which - from the simulated position of a joystick - will send the signals to the motor control systems. The achievement of automatic movements will thus require the calculation of a succession of virtual positions of the joystick.

2.2 Perception of the Environment

We have used two external sensors in our design. The first sensor is a camera, giving an outline of the environment which is understandable by the user. Currently, the use of video is dedicated for the user interface that we will detail below. The other sensor is a laser range finder sensor that enables us to measure a range of distances of 0 to 4 meters to the obstacles around the wheelchair on a circular plane of 0° to 240° with a resolution of 0.36°. These measurements are conditioned into a set of points characterized by their Cartesian co-ordinates in the frame of reference of laser sensor. Laser measurements are used to perceive the environment, and thus to program its movement.

Fig. 1. Vahm-3 wheelchair

Fig. 2. Interface with the user

2.3 Deictic Interface

The Human Machine Interface between the user and the wheelchair is designed to minimize the user workload, enabling him to control the wheelchair as simply as possible. As discussed earlier, the user has to provide two pieces of information to the system, the type of action to be carried out and the topographic localization of the target in the environment.

Concerning the first part, we currently confined ourselves to the behaviour "passing through a narrow passage". Thereafter a possible choice of behaviours will be introduced, proposing a selection of activation buttons presented to the user on the screen. For the second part, the user should indicate on the interface, the target localization in the environment. Thus the interface must present the most comprehensible vision of the environment to him. We have chosen to display the video image directly from the camera as a reflection of the environment (Fig. 2). On this interface, the coordinates of the target are determined with a click on the screen in the target area (currently this click is made via a mouse but we are considering other methods more adapted to users). This "click" has to be translated into topographic target point usable by the different elements of the system. This is a question of converting the point clicked on the screen, characterized by the coordinates (i, j) in the image, into the coordinates (x, y) of the corresponding topographic position in the plane of measurement of the laser sensor. This translation would be approximate, requiring simplifying assumptions. The first being the assumption that there are no obstacles between the camera and the point projected in the environment on the level of the laser sensor. In order to define a mode of conversion, the correspondence between certain particular points in the image and the environment is established as following.

Experimentally, we determine, in the environment, the positions of the points P2, P5 and P8, which are located in the image, in the centre of the lower edge, the centre of the image and the centre of the upper edge respectively. To do so, "landmarks" are placed in the environment so that they correspond to the points wanted on the screen and the distances ||OP5|| and ||P2P8|| are then measured in the environment. The Fig. 3 represents the correspondence between topographic localization and points of the image. The point (i, j) of the image is represented by its polar coordinates (ρ, θ) in the frame of reference of the laser. Knowing that the horizontal focus angle of the camera is 70° and that the dimension of the image is of 352*288 pixels we can calculate:

$$\theta = \frac{i \times 70}{352} \quad \text{and} \quad \rho \cong \frac{j \times \|P2P8\|}{288} + \|OP5\| \tag{1}$$

Then, starting from ρ and θ, one finds the Cartesian coordinates (x, y). This estimate supposes linear the relationship between the distances perceived in the image and those corresponding in the environment. It is acceptable for our application since on the one hand the passage is generally indicated to be in the vicinity of the middle of the image, and on the other hand the real localization of the narrow passage is determined with measurements of laser. Indeed, we use this conversion to obtain a first indication of localization of the passage, which allows thereafter, regain this position with exactitude thanks the laser sensor as will be shown in the next section.

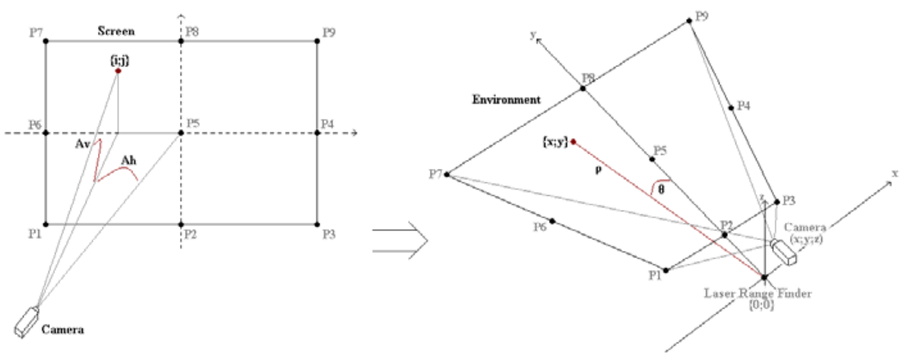

Fig. 3. Conversion of the click of the user on the video in Cartesian coordinates in the frame of reference of the laser

2.4 Detection of the Narrow Passage

In order to pass through a narrow passage, it is necessary to locate it precisely in the environment, at the beginning and during the movement of the wheelchair. Using the data from the laser sensor, this is carried out in the following way.

Firstly, in the frame of reference of the laser sensor, all the possible passages in the environment are sought. A passage is defined as space between two obstacles that is large enough for that the wheelchair can pass through. It is detected in the following manner. The points resulting from laser measurement are divided into sets of obstacle. For that, a sweeping of the points is carried out. A unit is created at the first point, then, for each point, the distance from its preceding point is measured. If the distance is smaller than the width of the wheelchair, then the point is considered to belong to the unit in progress, else, a new unit is created from this point. Once sets of obstacle are defined, the minimal passages between each unit are determined which will be memorized as a possible passage of the wheelchair. We can see on Fig. 4, an overview of the narrow passages characterized by a couple (cross, round). At the beginning of the trajectory, the passage closest to the point (x, y) calculated from the user input is selected as target, while the running passage, during the movement of the wheelchair, is determined as the closest to that used in the preceding stage.

As the wheelchair moves at a slow speed, the tracking toward the same target is guaranteed. The movement stops when the laser sensor detects that the passage has been passed, or otherwise, on the user's behest, who can click on the screen at any time to do so.

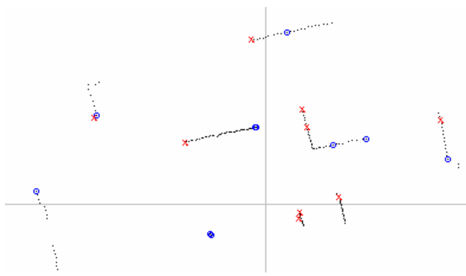

Fig. 4. Overall picture of passage in the environment on the cartography of our application

2.5 Trajectory Generation

In order to pass through a narrow passage, the wheelchair must be positioned well in front of it before entering. This requires the definition of a trajectory which brings the wheelchair in the good orientation. In our application, the trajectory is the result of a succession of target point. By observing the trajectories adopted by a person driving a wheelchair manually and taking into account the constraints of programming, the target points are defined in the following way. Several geometrical sectors are defined relative to the limiting points of the passage and for each sector; a target point is defined towards which the wheelchair will move in order to leave the sector. We actually want to reproduce, the behaviour of a person, who drives the wheelchair in front of the narrow passage with an orientation approximated before going towards the centre of the passage while refining the orientation. We thus create three areas, each having its target point as shown in Fig. 5. In this configuration, if the wheelchair is located in area 1, it moves towards the Pc1 point and as soon as it enters in area 2, moves towards the Pc2 point, and so on. The wheelchair doesn't reach really the target point as he changes of target when he changes areas. This allows a continuous motion and transitions between the targets points remain fluid. The Fig. 6 shows these areas and points during movement.

2.6 Control on a Position

At every moment, the objective (input to the system) is expressed by the polar coordinates of the target point. The wheelchair must thus continuously adjust itself in relation to this one. To achieve this, a digital PID controller has been designed to generate

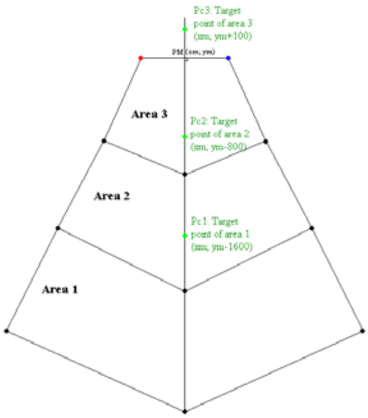

Fig. 5. Representation of the areas associated with their points target compared to the narrow

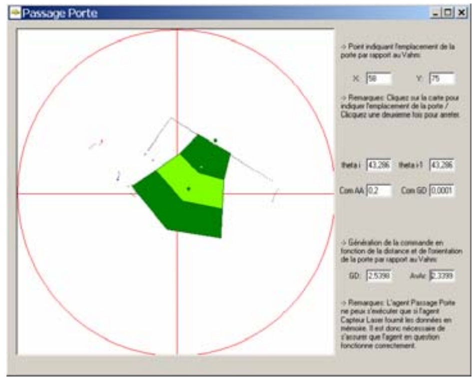

Fig. 6. Outline of the areas associated with their target points in our application

the simulated joystick signals. In the control feedback representation, the polar coordinates of this target point characterized by a couple (angle, distance) corresponds to the error of orientation and the error of position, respectively. The role of our controller is to cancel these two errors. A diagram of the control loop is shown on Fig. 7. The PID is adjusted empirically using the Takahashi Method. This method allows adjusting the parameters of the controller in closed loop and does not require any model of the wheelchair. After refining the adjustments the following gain parameters were obtained: P = 4; I = 0.01; D = 11.

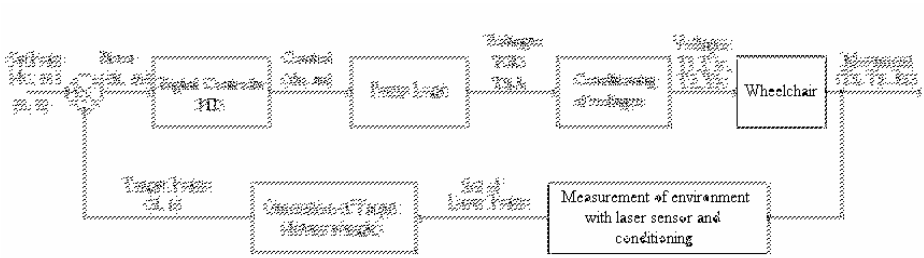

Fig. 7. Diagram of the control loop during a passing of narrow passage

3 Experimental Results

For the evaluation of the methodology, a set of tests were achieved to verify its operating mode and to estimate its operational limits. A great number of courses were carried out in different places in our laboratory. Three of them are described here. For each test, an outline of the environment on the user interface is given, as well as the trajectory followed by the wheelchair. On the environment image, the arrow indicates the target pointed by the user to launch movement. The trajectory is obtained indirectly, starting from the succession of laser measures, as follows. During the execution of the procedure, the location of the narrow passage, perceived by the laser sensor, is memorized at each measurement. Thus, the movement in the narrow passage in relation to the laser reference is obtained. For more legibility, the reference frame is changed by fixing the target passage while the wheelchair is shown to move. Then, the localization of the wheelchair in this frame is recovered by projection. Thus, a trace of successive positions of the wheelchair in relation to its target is obtained. On the trajectory, the wheelchair is represented as a rectangle corresponding to its maximum expanse.

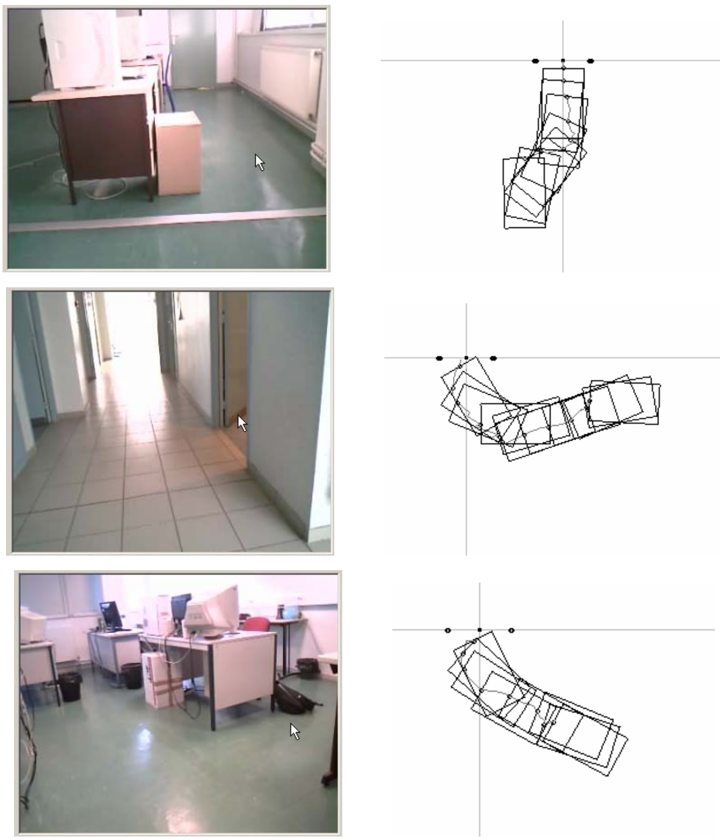

Fig. 8. Tests presenting the starting vision (on the left) associated at the trajectory of the wheelchair in this configuration (on the right)

The process of passing through the passage is considered to have been completed when the laser sensor (located in front of the wheelchair) is passed through the target. The trajectory thus stops at this stage. Then, the wheelchair must be able to pass through the narrow passage, from where the importance of a good orientation.

This functionality can be employed to pass through several types of obstacles, a door, between two tables, or two obstacles unspecified. The tests described in Fig. 8 illustrate it. It is noticeable that the trajectories obtained are close to those which a human would have followed manually. For example, one can see in the second test, that the wheelchair moves away from the door so as to approach this one in face. This is made possible by our method of trajectory generation. One can thus see the importance of the repositioning and orienting before entering. Indeed, if the wheelchair takes aim at the centre of the passage from the beginning, he could not pass this one. The fluidity of the movements can also be noticed by analyzing the variation of distance between the rectangles. The expanse of the wheelchair has been represented by a rectangle at each interval of three measurements, i.e. at regular time. The difference between the rectangles thus represents the speed of the wheelchair during movement which is almost constant (around 0.3m/s).

4 Discussion and Conclusion

The implementation of this first functionality and the profitable tests carried out show that this association command by vision and control by laser is a promising design for the deictic control of smart wheelchairs. During the many tests carried out, two types of limits could be identified. First of all, the limits of the methodology itself are put in highlight as follows. So that the functionality of narrow passage is efficient, the wheelchair must start from a certain distance from the passage (at least 1m), since it must follow a succession of target to pass through the objective. If it is too close, the target point retained would actually be the centre of the passage. It would arrive in front of the narrow passage with a wrong orientation and fail. In such a configuration a human driver would do a manoeuvre before entering.

The second limitation is of technological nature, primarily due to the characteristics of the sensors. The angular focus of the camera limits the possible passages to those visible on the interface. Furthermore, the perception of the laser is limited to an angle of 240°. It is possible, that in follow-up of the trajectory if the wheelchair must move away from the objective, this one can go out of the measurement field of laser sensor. These technological limits can easily be overcome by modifying the used devices (for example by taking a camera with larger focus or by adding a second laser sensor).

One could show here that the complementarity between laser and vision is operative for the control of the smart wheelchair. The deictic control that we conceived and illustrated on the functionality of passing through of narrow passage gives satisfactory results. In order to achieve a command entirely designed on this model it will be necessary for us to develop other functionalities such as direction following, docking and wall following.

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Pervasive Informatics and Persistent Actimetric Information in Health Smart Homes

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Abstract. This paper discuss the ability to obtain a reliable pervasive information at home from a network of localizing sensors allowing to follow the different locations at which a dependent (elderly or handicapped) person can be detected. The data recorded can be treated as the sequence of color coding numbers of balls (symbolizing activity-stations) taken in a Polya's urn, in which the persistence of the presence in an activity-station is taken into account by adding a number of balls of the same color as the ball just drawn. We discuss the pertinency of such a procedure to early detect sudden or chronic changes in the parameters values of the random process made of the succession of ball numbers and we use it to trigger alarms.

1 Introduction

Since about 12 years [1]-[3], many experiments have been achieved for watching dependent people at home, in particular elderly and handicapped persons. In order to acquire data necessary to permit the alarms triggering, numerous sensors have been invented, in particular for localizing the person at home or in the surroundings. These localizers are on the body (like the GPS or the accelerometers), in the flat rooms (on the walls, like the infrared or radar detectors or on the ground, the bed or the chairs, like the pressure sensors, *cf.* Figure 1), on the doors (like the magnetic switches) or in gardens and streets (like the video-cameras). The sensors network is very important to follow up the dependent people during their walk trajectories inside home or outside. If the space/time data are acquired on healthy elderly people or on patients suffering from a neurodegenerative disease, the sensors recording must be very well calibrated, to give birth to specific profiles of the time series corresponding to the successive locations in rooms inside the flat or in specific places inside a room [8]. A big hope comes from this ambient information to be able to detect a progressive stereotyped behavior (for the early diagnosis of a chronic disease like the Alzheimer one) or a sudden fall on the ground. The optimal use of this pervasive information implies fusion and scoring from the primary data, in order to detect minimal changes in time profiles: a way to do that is to considerably simplify the information by giving a color coding number to the different locations (pertinent for the

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watching), and to follow up the succession of these numbers, *e.g.* by interpreting them as the succession of colors of balls drawn from a Polya's urn: in this kind of urn, the persistence (or *a contrario* the unstability) of an action in a location is represented by adding $n_i(k(i))$ balls of color $k(i)$, when a ball of color $k(i)$ has been obtained at time i. If $n_i(k(i))$ depends only on i through k, the random process constituted by the succession of the $n(k(i))$'s is called homogeneous and a change in homogeneity can be detected by estimating the $n(k)$'s and testing their significant consecutive differences. We will give in the following elements of material and methods in order to describe more precisely the data collection and treatment procedures, and then we will discuss the pertinence of such a research protocol and its implementation in the current life of dependent people at home.

Fig. 1. Infrared (arrows) for localizing dependent people in a health smart home (left) & pressure sensors (right: FSA Seat 32/63 pressure mapping system, Vista Medical Ltd)

2 Material and Methods

A private apartment of an older woman, aged 80, at the Institution Notre-Dame (Grenoble, France) is equipped with a health integrated smart home (HsH). In general, the underlying principle of the HsH consists in continuously collecting data regarding her individual activity within her home environment and sending them to a telemedicine center via electronic mails (SMTP). As illustrated in Figure 2, our experimental health smart home includes 7 presence infra-red sensors (DP8111X, ATRAL), allowing the detection of the infrared radiations emitted by body surfaces (face, hands), and hence the monitoring of individuals successive activity phases within her home environment [10]-[13].

These different detections are timestamped and stored in a database (SQL) and then transmitted by e-mail through an attached file (XML). They permit the continuous real-time surveillance on the screen of a dedicated workstation at

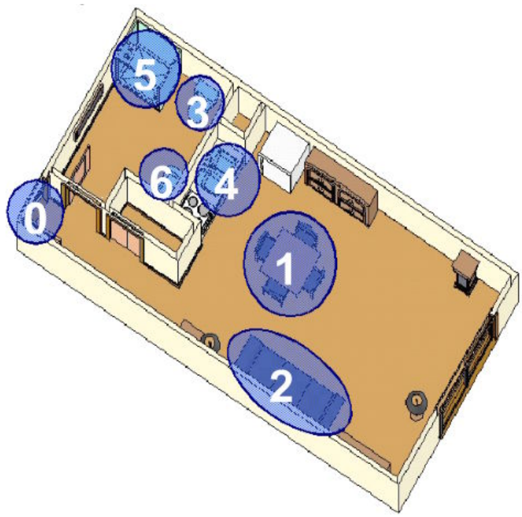

Fig. 2. Architecture of the experimental health smart home. Location sensors are placed at different places in the apartment, allowing the monitoring of individuals successive activity phases within his/her home environment: **0.** Entry hall - **1.** Living room - **2.** Bedroom - **3.** WC - **4.** Kitchen - **5.** Shower - **6.** Washbasin.

the Hospital at Home (HaH) service which possesses nurses and doctors ready to visit the person at home in case of an acute pathologic problem or to transmit to a chronic disease service the information about the occurrence of a problematic change in the physiologic variables recorded at home (cf. Figure 3 left and center).

The data analysis of the records at home is primarily done through real-time updated descriptive statistics like presence histograms (Figure 3 right) but it is also achieved by using more sophisticated random processes techniques like time series or Polya's urns. The random processes made of the succession of the recorded localization data have been indeed already modelled by using classical time series techniques like Box-Jenkins auto-regressive processes in which were extracted the entropy [2] or the coefficients of the linear auto-regression [15]-[19]. In this paper,the information to be treated is reduced at the minimum and the only thing retained is the succession of the activity-station-codes corresponding to the successive locations of the elderly people at home. An important feature to extract from the random process made of the succession of these activity-station-codes is the breaking times at which a specific model of Polya's urn is no more avalaible, obliging to change the values of the parameters $n(k(i))$'s corresponding to the (algebraic, possibly negative) number of balls which must be added after obtaining a ball of color $k(i)$ at time i. It is supposed that if there is no pathologic change (sudden due to a fall or chronic due to the entrance in a neuro-degenerative disease), $n(k(i))$ is not depending explicitely on the time i, but only on the activity-station-code $k(i)$.

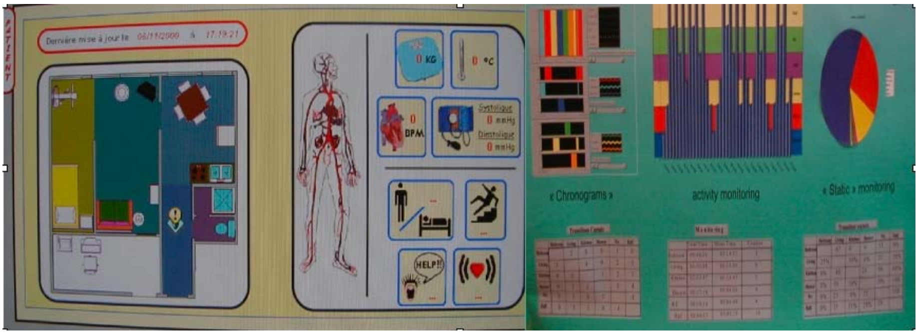

Fig. 3. Watching workstation at the HaH (Hospital at Home) service for the surveillance of dependent people at home

The first use of Polya's urns to represent persistence in a succession of qualitative data has been done since 25 years by climatologists for the sequence of dry and wet days [4,23], and a lot of fundamental [5,7,22], or more applied [6,9,14], papers have been after published for studying the theoretical properties of the corresponding random process, or for estimating its parameters or its thermodynamical variables (like the entropy of its stationary distribution).

The Polya's urn scheme is a Markov chain in which the balls are sequentially drawn from an urn initially containing a given number $a_0(j)$ of balls of the j-th color, $j = 1, \ldots, N$, and after each draw the ball is returned into the urn together with $n(j)$ new balls of the same color j. It is assumed that we observe at time i the $a_i(k)$'s (corresponding to the number of balls of color k drawn from the Polya's urn at time i) and $b_i = \sum_{c=1}^{N} a_i(c)$ balls and that we estimate the parameters $n(1), \ldots, n(N)$ supposed to be positive, by observing the frequencies in m trials of occurrence of balls of corresponding colors. For processing the estimation of $n(j)$'s, we consider the integer-valued random vector denoted $a_i = (a_i(1), \ldots, a_i(N))$ and distributed, if $n(j) \geq 0$, in the set:

$K_N = \{k = (k_1, \ldots, k_N) : k_i \text{ integers } / s = \sum_{c=1}^{N} k_c \geq b_0 = \sum_{c=1}^{N} a_0(c)\}$

according to:

$$\forall i \in \{1, \ldots, m\}, \quad P(\{a_i = k\} \mid a_{i-1}) = \begin{cases} \frac{a_{i-1}(j)}{b_{i-1}}, & \text{if } k_j = a_{i-1}(j) + n_i(j) \text{ and } \forall r \neq j, k_r = a_{i-1}(r) \\ 0, & \text{if not,} \end{cases}$$

where $n_i(j)$ is the number of balls of color j added at time i. Let us denote $n_i = \sum_{c=1}^{N} n_i(c)$ and suppose that $n_i = Np > 0$, where p is the mean persistence rate (supposed to be independent of the time). When the n_i's are equal, the probability above reduces to:

$$\forall i \in \{1, \ldots, m\}, P(\{a_i = k\} \mid a_{i-1}) = \frac{a_{i-2}(j) + p}{b_{i-2} + p},$$

where j is the index in $\{1, \ldots, N\}$ for which we have: $k_j = a_{i-1}(j) + p$ and $\forall r \neq j, k_r = a_{i-1}(r)$.

Then we can calculate the probability $P(\{a_i = k\})$, when $k_j = a_0(j) + s_j p$, by using the formula:

$$\forall i \in \{1,\ldots,m\}, \quad P(\{a_i = k\}) = C_i^{k_1,\ldots,k_N} \frac{\left[\prod_{j=1}^{N} \prod_{s_j=0}^{\frac{k(j)-1}{p}} (a_0(j) + s_j p)\right]}{\prod_{s=0}^{i-1}(N + sp)},$$

where the k_i's verify: $k_i \geq 0$ and $\sum_{c=1}^{N} k_c = i$.

Let us now consider possible strategies of estimating the persistence p and the initial distribution a_0:

1) If we know the initial distribution of balls a_0, observing the empirical frequency $f(\{a_i = k\})$, we can estimate p by calculating the likelihood function and using the maximum likelihood estimator

2) If we do not know the initial distribution nor the persistence, we can:

- either estimate it by deciding that b_0 is fixed to a multiple of the number of activity-stations (*e.g.* twice this number) and by using a procedure similar to those proposed in [6], by supposing p known, and after deriving this initial estimation as function of p, finally trying to fix p at the integer value maximizing the likelihood function

- or, if the attempt above is not succeeding, to assume the uniformity of the initial distribution (*i.e.* decide that the initial number of balls was the same for each color/activity-station).

In the case where: $\forall j \in \{1,\ldots,N\}, a_0(j) = 1$, the probability of having the balls vector equal to k at time i becomes:

$$\forall i \in \{1,\ldots,m\}, \quad P(\{a_i = k\}) = C_i^{k_1,\ldots,k_N} \frac{\left[\prod_{j=1}^{N} (\prod_{s=0}^{\frac{k(j)-1}{p}} (1 + sp))\right]}{\prod_{s=0}^{i-1}(N + sp)},$$

where the k_i's verify: $k_i \geq 0$ and $\sum_{c=1}^{N} k_c = i$.

Then by replacing $P(\{a_i = k\})$ by $f(\{a_i = k\})$, we can estimate p. The empirical frequency $f(\{a_i = k\})$ is calculated from observations done at different days supposed to be independent (the initial distribution a_0 is suppposed to remain the same at the beginning of each day and the days are supposed to be independent). If there is 2 persistence parameters to estimate, *e.g.* p for the living (activity-station number 1) and p' for the other activity-stations, we can use a sequential probability ratio test (SPRT) procedure [21] by considering that there are only 2 super activity-stations codes, 1 for the living and 2 for the other activity-stations and by trying to estimate the best sampling size threshold allowing a significant decision in testing the hypothesis $H_0 \equiv \{p = p'\}$ (*i.e.* the persistence is the same in the two super activity-stations) against $H_1 \equiv \{p \neq p'\}$ (*i.e.* the persistence is different in the two super activity-stations).

3) If we have no information about the initial distribution of balls a_0 (even concerning the initial total number of balls b_0), but if we suppose that there is the same persistence in each activity-station, we can follow during a sufficient time the activity of the dependent person at home and estimate the conditional probability:

$$P(\{a_{i+1}(j) - a_i(j) = 1\} \;\Big|\; \{a_i(j) = k\}) = \frac{a_0(j) + kp}{b_0 + ip}$$

By replacing the conditional probability above by the corresponding conditional empirical frequency (estimated from series of independent activity days for different activity-stations), we can get an estimation of p. We can also perform a test of $H_0 \equiv \{p = 1\}$ against $H_1 \equiv \{p > 1\}$, by comparing the empirical frequency of the event $\{d_{i+1}(j) = 1\} \cap \{d_i(j) = 1\}$ (*i.e.* the frequency to have consecutively the same color j, if $d_i(j)$ is the number (0 or 1) of balls of color j drawn from the Polyas's urn at time i) to its theoretical probability, which is binomial under H_0, with the probability to draw a ball j at time i equal to $\frac{a_0(j)}{b_0}$. When i increases, the estimation of $\frac{a_0(j)}{b_0}$ becomes rapidly very precise and allows the use of a classical test of comparison between an empirical and a theoretical frequency.

In the present case of persistence in activity-stations, we can assume that after a series of presence in an activity-station equal to or more than 2 recording intervals, if the activity-station changes, that involves a reset and we return to the distribution a_0. Then, we can use the following sequential procedure for tests : i) initially as above $H_0 \equiv \{p = 1\}$ against $H_1 \equiv \{p > 1\}$,
ii) if H_0 is rejected, $H_1 \equiv \{p = 2\}$ against $H_2 \equiv \{p > 2\}$,
iii) if H_1 is rejected, $H_2 \equiv \{p = 3\}$ against $H_3 \equiv \{p > 3\}$, ...

until we reach, with the value of $p = k$ at the step k, a probability of activity-station changing (rejection of H_{k-1}) in k steps more than the threshold value 0,95.

3 Data and Results

The files treated bring together the data recorded in the flat of the elderly people in a period of 8 months from the 24$^{\text{th}}$ of March 2005 until the 25$^{\text{th}}$ of November 2005. The file follow the structure:

Table 1. The times and locations of the records

Day	**Month**	**Year**	**Hour**	**Minute**	**Second**	**activity-station-code**
24	03	2005	17	37	36	1
...						

The columns represent successively the time (with the day, month, hour, minute and second of the recording) and the activity-station-code corresponding to the location of the watched person at this time.

From these records, we have tested different hypotheses about the persistence following the procedure given in the previous Section. We will give below on a short example a sketch of our testing strategy. The data for 200 record times were used for performing the two following steps:

i) - we calculated the empirical frequency $\frac{a_0(1)}{b_0} = \frac{58}{200} = 0.29$

- we use it for testing H_0 against H_1. The probability to observe 2 consecutive stays in the living (activity-station 1) is equal, under the hypothesis H_0 to $0.29 \times 0.29 = 0.084 \pm 0.06$ (the variance of an empirical frequency observed on a records sample of size i being estimated by $\frac{f(1-f)}{i}$). Then the hypothesis H_0 is rejected with a significativity less than 1/1000: large deviations (with probability less than 1/1000) of the number of pairs of consecutive stays in living start at the value 29, and there are 31 such pairs in the records .

ii) by pursuing the sequence of tests, we found that $p = 3$ is the best estimation of the parameter of persistence in the living, because it is the first integer giving probabilities 6/10, 6/13, 6/16, 6/19 and 6/22 of exiting from the living after respectively 1, 2,..., 6 stages in this activity-station. These probabilities have been estimated by the corresponding empirical frequencies of exit from the living after 1, 2,..., 6 stages. These empirical frequencies were respectively equal to $14/24 \pm 0.06, 4/9 \pm 0.06, \ldots, 1/3 \pm 0.07$ in the experimental records of 200 sampling times.

4 Discussion

We have assumed in the previous calculations 5 important hypothesis we can now discuss:

1) the activity is homogeneous in time and space inside a day, *i.e.* we have the same persistence for each activity-station sojourn and a reset of the persistence memory at the end of a sojourn.

We have surely a persistence more important in activity-stations in which several tasks can be done involving a long time investment, compared to stereotyped and standardized tasks done in other activity-stations.

2) the activity records sequence is a Markovian process, for which the future depends on the past only through the present.

There are surely some breaks of the Markovian character, specially during activities asking for more attention (like cooking or reading), in which a time series approach would be more convenient than the Polya's urn modelling (the classical time series treatment involves the extraction of a tendency through a mobile time window, and then the calculation of a time linear regression order [2]).

3) the role of the activity-stations is symmetrical, *i.e.* each activity-station generates the same initial conditions in the initial distribution of balls (representing activity-stations) in the Polya's urn.

Because of many differences of surface, functionality, illumination, the activity-stations are not playing the same role and have different weights after resetting, depending on the time in a day (certain tasks being executed only once at a fixed hour of the morning or afternoon).

4) the persistence is non depending on the time

In fact, there are nycthemeral variations of activity ([15,16,18]) as well as seasonal effects we have to take into account for making more precise the statistical structure of the persistence. A remanence of the persistence surely exists, especially at the end of day where the level of awakeness and attentiveness is diminished.

5) successive days can participate to the same independent identically distributed (iid) sampling.

In fact, there is certainly a dependency linked to the place of the days in the week (Saturday being for example used for recapitulating the working days activity and for anticipating the leisure organization of Sunday).

5 Conclusion

The monitoring of dependent people at home allows the recording of their activity, especially the activity-station changing sequences, what is very useful to detect deviances with respect to the normal behavior. The detection of large deviations from the "normal" individual distribution of the random process retained for the ordinary walking of a dependent person inside his flat, permits to anticipate the fall, whose risk is high and renders it ineluctable a day, after 80 years. The fixed or embarked localizing sensors give sufficient indications to trigger an alarm at the level of the patient (for a real-time correction of a desequilibrium, in case of vestibular pathologies [20]) or at the level of the Hospital at Home service (for an emergency sending nurses or doctors, depending on the gravity of the detected dysfunctioning). The body sensors are incorporated in ordinary clothes rendering the surveillance ergonomically acceptable. We are now developping techniques for studying (like for a drug), the "toxicity" of the watching system, toxic here meaning unaesthetic, intrusive, invasive and/or pathogenic, the level of toxicity depending on the "compliance" of the recorded subject. We present the beginning of such studies in a companion paper in the present issue [20] and we will develop further psycho-physic studies for the determination of the liminal level of sensitivity/specificity and of the level of rejection, necessary for quantifying the degree of acceptability of the sensors network studied in this paper.

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Interactive Calendar to Help Maintain Social Interactions for Elderly People and People with Mild Cognitive Impairments

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Abstract. Today's societies are very different from those of the past. The proportion of elderly people is growing steadily and has reached highs never reached before. Cases of dementia have also risen as the population gets older. Family members often live far apart and it is not unusual for them to be scattered in more than one country or continent. Memory loss associated with ageing (and amplified in cases of dementia) as well as a general feeling of isolation caused by distance can often lead elderly people to depression. We believe that, if used properly, technology could provide elders with powerful memory aids and social interaction tools that could improve their quality of life. In this article, we propose the use of a special interactive calendar with enhanced functionalities that can help manage a schedule, keep in touch with family members living far away, and reminisce about past events.

Keywords: Memory aid, social interactions, elderly, ageing, calendar, intuitive tools.

1 Introduction

The proportion of elderly people in our societies is growing steadily. Global ageing is such an important phenomenon that, in 1998, it was estimated that 50% of the people who lived long enough to reach their 65th birthday or more were still alive [1]. Furthermore, statistical studies predict that more than 60 countries will have at least 2 million elderly people amongst their total population within the next 20 years [2]. Because people tend to live longer, various forms of dementia, such as Alzheimer's disease, are also on the rise. According to the Canadian Alzheimer Society, Alzheimer's accounts for 64% of all dementia cases [12]. Approximately one Canadian in three knows someone who suffers from Alzheimer's disease and almost one Canadian in five has a family member with Alzheimer's. Approximately half of the people with dementia live at home alone or with a caregiver (family member or other) [12]. France Alzheimer estimates that 1,3 million people will have Alzheimer's disease in France within the next 10 years [13].

As people grow older, they tend to experience more memory lapses, which is why a lot of them rely on some kind of low-tech memory aid(s) such as post-it notes, paper calendars, note books, alarm clocks and timers, to compensate for memory loss [3]. Elderly people with dementia such as Alzheimer's are even more prone to memory

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lapses and often suffer from temporal disorientation. They can have difficulties managing their daily schedule (appointments, medications, birthdays, etc.) and also tend to feel more isolated as they often forget about past visits from family members thus giving them the impression that no one visits them.

In today's societies, people are extremely mobile. It is not unusual for family members to live in different countries, even on different continents. Grandparents do not get to see their children and their grandchildren as often as they would like and this can lead to feelings of isolation that can lead, in turn, to depression in some cases. As modern societies change, it is important to find new means to help our elders keep in touch with loved ones and continue to live an active life in their community as well as in the new emerging "global community".

Contrary to a popular belief that is still strong today, elderly people see the use of new technologies as positive and desirable if it can help improve and maintain their quality of life all the while respecting their privacy [4][5][6][7]. A study conducted by [3] describes elderly people who are more inclined to use some kind of electronic memory aid as being generally well educated, as having least a little bit of experience with other electronic devices such as computers and, obviously, as suffering from occasional memory losses.

Even though there are a lot of electronic memory aids on the market today, most of those devices are not adapted to the needs of the elderly population [10][11]. The screen, labels, buttons and keyboards are often too small; the devices are usually complex to use and have too many options; etc.

Given the potential benefits of using technology to provide elderly people with powerful memory aids and new social interaction means and the lack of tools specifically designed for this segment of the population, we want to provide a simple, pleasant and convivial tool which will:

- Require little or no adaptation and/or training on the part of the user
- Integrate itself seamlessly in the elderly's home
- Help the user to recall appointments and social activities
- Help reminisce about past events such as a visit from a family member
- Help keep in touch with family members who live far away
- Be customizable in accordance to the user's needs, abilities and preferences

We hope that by providing elders with user-friendly technology, designed to help manage their schedule and to keep in touch with family and friends, they will feel more in control of their own lives and more in touch with their community. The tool we have chosen is an interactive calendar. In the next section, we will describe the calendar and how it could be used to improve social interactions.

2 The Interactive Calendar

We want our calendar to be easy to use for elderly people who have little or no experience with computers and technology in general. It means that our interfaces must be simple and intuitive in order for them to require little or no training and/or adaptation on the part of prospective users. This aspect is all the more important as we want to help people with mild cognitive impairments as well as elderly people with no known cognitive disorder.

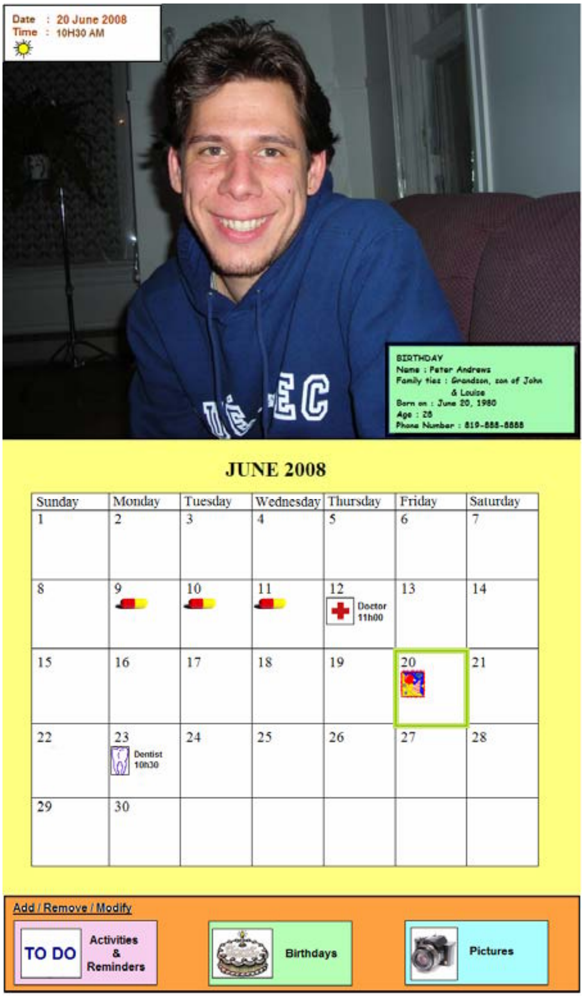

Fig. 1. One of the first prototypes of the Interactive Calendar

We want to rely as much as possible on knowledge and habits which were learned and assimilated early in life because they are the ones which are most firmly ingrained (thus making them easily accessible and often automatic) and among the last to degrade with time. Our calendar must thus have the look-and-feel, both visually and as far as the basic functionalities are concerned, of already familiar tools. The notion of familiarity is a key element because it "(…) *is based on the theory that long-term memory is generally more intact than short-term, recent memories for people with dementia. This means that ingrained and well-learnt skills from earlier in life can be retrieved when opportunities within the environment promote their use (e.g., an analog clock instead of a digital one, a sink of soapy water instead of a dishwasher, a rotary phone instead of a touch-tone model, etc.). Therefore, (…) it is* *important to maintain as much as familiarity and consistency as possible in the environment. The more familiar an environment is, the more supportive it will be.*"[8]. The positive impact of familiarity is also true for people who do not suffer from any form of dementia and will also benefit users with some experience with technologies.

To facilitate its use, our calendar is made to look as much as possible like its paper counterpart (see Fig1). There is a picture on its upper part and a set of large boxes, one for each day of the month, on its lower part. The box representing the current day is highlighted (framed in bold with a distinctive background color and with a larger font for the date). The current date is also written in full (ex: Saturday, February 14, 2009) in the top left corner of the calendar's picture, in addition with the time of day and an icon (a sun or a moon) which serves as an additional temporal cue.

The user can interact with the calendar in many ways. For example, by touching an icon (ex: a pill, a cake, etc.) in one of the calendar's day boxes, a detailed written description of the activity represented by the icon can temporarily replace the calendar's main picture OR a pre-recorded audio message (recorded by the user, or a family member, beforehand) containing information about the activity can be played. Automatic reminders can be customized according to preferences stated by the user. The system can "remind" to user by using different means such as visual cues (ex: changing the main picture of the calendar, modifying the ambient lighting, etc) and audio cues (chimes, audio messages on speakers, or pre-recorded automatic phone calls).

2.1 New Means for Social Interactions

Unlike a paper calendar, our interactive calendar has the potential to be more than a simple memory aid for appointments and medication. It can help maintain and strengthen social interaction as well as act as a reminiscence tool that enables users to "revisit their past". The picture at the top of the calendar can change automatically, not only according to the month, but also according to the day (ex: Halloween) or to the activities to be performed. For example, when it is the birthday of a friend or a family member, his picture, his name, his complete birth date (ex: January 23, 1969), his phone number and his affiliation (ex: grandson) are displayed in the top half of the calendar. Seeing the picture could act, for some people, as a form of reminder to call a grandson or a granddaughter in order to wish him or her happy birthday.

As another example, a relative or friend who is visiting can, if he wishes it, insert in the calendar a digital photograph taken during his visit as well as a short message to accompany it. The photograph will then be an integral part of the calendar and will be available for display on the top half of the calendar whenever the user touches the smaller version of the picture located inside the box corresponding to the day of the visit. As the use of clues and cues can help stimulate the recovery of information (past memories) [9], we believe that such a photograph inserted by a friend or family member could prove to be a good means to help the user reminisce about visits and other special occasions. This feature could prove interesting for people with mild dementia who tend to forget about past visits. For example, a daughter visiting her mother who suffers from Alzheimer's could use the pictures previously stored by her brother to initiate a conversation about his last visit.

The calendar can also be used to keep in touch with family members living abroad. Here are a few examples:

- Eleven year-old Julie wants to send a drawing to her grandmother who lives in Australia. She asks her father to scan her drawing and then goes on a dedicated web site that enables her to send her drawing, along with a personal message, to her grandmother. The drawing and the message are then automatically displayed on the top half of her grandmother's calendar. Every time Julie's grandmother looks at her calendar, she now sees Julie's lovely drawing.
- Mark, an 18-year-old college student, is at his school's library. It is his first year in Germany away from his family and today is his grandfather's birthday. Through a dedicated web site, Mark can send a personalized greeting card to his grandfather in England. As soon as the greeting card is sent, it appears on his grandfather's interactive calendar for him to see.

2.2 Three Levels of Functionalities

In order to take into account novice users, intermediate users and expert users, our calendar has three different levels of functionalities.

Basic functionalities are easy enough to be used by elderly people with no experience with computers while still being interesting for people who are more comfortable with the use of new technologies. These functionalities are as simple and as intuitive possible in order to require no (or very little) training and can be regarded as being the "minimal/essential" set of functions that can be used by all users. These functionalities pertain mostly to passive consultation of the calendar. They include the general functions of a paper calendar such as displaying the days of the month with special notes on the days the user has appointments. Highlighting of the box representing the current day (framed in bold with a distinctive background color and with a larger font for the date) and displaying in full the current date (ex: Saturday, February 14, 2009) in the top left corner of the calendar's picture, in addition with the time of day and an icon (a sun or a moon) which serves as an additional temporal cue are also examples of basic functionalities.

Intermediate functionalities are options which should be fairly easy to use by elderly people with little to no experience with technology. However, if a user should ever start to experience a decline in their cognitive abilities (such as the beginning of dementia), the use of those functionalities could possibly be forgotten as their condition further deteriorates. These functionalities are sufficiently intuitive to be quickly learned by somebody who does not have any experience with computers and to be almost obvious for somebody who has a minimum of preliminary knowledge on computers or other similar devices. Intermediate functionalities are for dynamic consultation of the calendar and require the user's input.

For example, the user can "flip" the pages of the calendar in order to have an overview of previous or next months. He can also access a more detailed description of the activities related to a specific day simply by pressing on the appropriate day box in the calendar grid. He can then go back to the regular display by touching the "Close" button.

Advanced functionalities are related to data entry. They are more difficult to use and will require more practice for elderly people with no experience with computers. However, since more and more people are familiar with technology, we believe they will be easy to use for the "elderly of tomorrow" who will have been exposed to information technologies throughout their lives. In the meantime, those functionalities will be mostly used by elderly people with some experience with computers or, in the case of computer novices or people with mild dementia, with the help of younger family members or caregivers. Here are a few examples of advanced technologies:

- Entering new information pertaining to birthdays or modifying information, such as a phone number, regarding an already existing contact.
- Entering information on new appointments or on new medications
- Customizing the automatic reminders according to the user's preferences.

3 Testing and User Input

The calendar is developed with the user constantly in mind. Testing and user input are therefore important parts of the development process. Three different types of user input and testing will be used in three phases.

Phase 1. Focus groups composed of social workers and elderly people with little or no experience with computers will help us evaluate the look and feel of various prototypes and gather information as to what functionalities are more desirable and useful.

Phase 2. Individual testing sessions based on scenarios followed by interviews & questionnaires, in which the participants will be elderly people with various degrees of experience with computers (mostly novice and intermediate users), will help us evaluate the usability of the calendar. These sessions will help us answer questions such as:

- Is the learning curb important or negligible?
- Which functionalities are the hardest to use/learn and how can we improve them?
- Are the users able to complete the scenarios?
  - If not, where did they encounter problems?
- How many and what type of mistakes did the participants make?
- How long did it take to complete the various scenarios?

These testing sessions will require the help of 12 to 15 elderly people, some of which will be first time participants, while others will be chosen among the phase 1 participants.

Phase 3. Finally, the calendar will be tested in the homes of 3 to 4 elderly participants for a period of one month each in order to test the reminder functions and the "keep in touch" functions, see which functionalities of the calendar are used the most, and validate with the elderly the integration and use of the calendar in their own homes. For testing purposes only, the calendar will record the actions of the user e.g. which icons/functions were selected/used, when they were used, etc.

4 Conclusion

Elderly people are far from being technophobes and are more than willing to welcome technology in their own homes if that technology can improve their quality of life without being invasive and hard to use. Since memory loss is part of the normal ageing process and since most elderly people already use some kind of low-tech memory aid, we believe that the use of new technologies is the next logical step. The use of a customizable interactive calendar such as ours could also prove to be benefic for people suffering from mild dementia who have problems keeping up with their daily activities and tend to forget not only about their future appointments, but about past events as well. Finally, as it is more and more frequent for family members to live in different parts of the world, the use of our calendar could help elders and their family and friends keep in touch in a pleasant and non invasive way.

The response to our project so far has been quite positive. Phase 1 of the project is now underway and will be completed in May 2009.

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Situation-Theoretic Analysis of Human Intentions in a Smart Home Environment

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Abstract. Smart home environments often need personalized requirements based on existing service products. Requirements under the environment may change at any time, even while services are correctly provided, since both caregivers and residents eventually diversify their intentions. In this paper, a situation-theoretic framework to infer human intentions is presented through a smart-home demonstration aimed at supporting independent living of elderly people. By analyzing experimental sensor data collected from a real-life smart home, differences and similarities between three detected intentions were intensely discussed.

Keywords: context-awareness, evolution, goal, human intention, requirements, service, situation theory, smart home.

1 Introduction

Today, it is often advocated that at the design stage, requirements engineers, system designers, and other stakeholders can specify situations as collections of contexts and corresponding services [1]. System and software requirements, however, may not cover all the possible situations. Context-aware systems often fail to effectively evolve to accommodate dynamically changing service requirements because of their inability to acquire human intentions from context information.

Human intention has treated it as plan to achieve a declarative goal [2]. This paper discusses the possibility to infer an intention from situations through a window of observations. There is an important issue that humans are open systems; they can learn, and often change their desires. Desires (or human mental states) often lead to a new goal during service runtime. Therefore, software developers are often challenged by such a complex "goal management" process where predefined system requirements may eventually become temporarily obsolete or contrary to an intention. Thus, the changed intention often results in modified or new goals for the user, requiring the modification of existing features or creation of a new functionality [3] [4]. Such a cycle of observation, modification, development and deployment may consume developers several months or several weeks to complete with the current state of the art. In our view researchers must endeavor to shorten such a long cycle to a few days, a few hours or even a few

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minutes, and devise new evolution mechanism to modify existing or create new services at runtime.

In this paper, we give a concise introduction to a situation-theoretic framework for runtime service evolution, and in that context present real-world data analysis through a smart-home demonstration aimed at supporting independent living of elderly people. The situation-theoretic framework provides a monitoring process to observe human actions and infer human intentions. Such a framework is capable of supportiing rapid and iterative service requirements analysis of real-world systems at runtime.

2 Situation-Theoretic Framework

2.1 Situation and Intention

Observation of human intention has been recentry studied in sensor-based approaches [5]. There is an emerging research that focuses on temporal context-awareness where user-centered situations, such as location can be taken into account for computation to support improved life style [6]. In our view, human intention to obtain a service sometimes includes potential, valuable service requirements. An intention is considered as temporal sequence of situations to achieve a goal; any intention is supposed to work as a constraint for satisfying the goal, which is specified as requirements [7]. The novelty of this study lies with our definition of situation that is semantically richer than the prevailing definitions [1] [8] for context-aware services environment.

In our framework, system designers observe intention changes based on the temporal sequence of situations. While monitoring intentions, service requirements are maintained and updated to meet each individual service user's evolving desires. For example, lifestyle is gradually changed to maintain wellness of residents in a smart home. Maintenance processes for body wellness varies from person to person. Sometimes timely services would be required for a sudden situation (e.g., one of the residents found missing) even if such situations were not precisely defined as specification.

2.2 Intention Monitoring

In our situation-theoretic framework we decompose contexts into two subdomains: behavioral contexts and environmental contexts. Behavioral contexts are manifested in human actions. Environmental contexts are categorized as lower level contexts that are subject to bi-directional interactions with the behavioral contexts (i.e., sensing and actuating). Both behavioral and environmental contexts are drawn from the raw data (Figure 1).

Given the highly complex human actions captured from sensor data, we propose to address the issue to infer human intention from a multi-level perspective. At the lower level, we use Hidden Markov Model with Dirichlet Process to capture changes in desire states through observable-parameters-based inference (for the entire framework, please see [7]). In this paper, we describe the idea

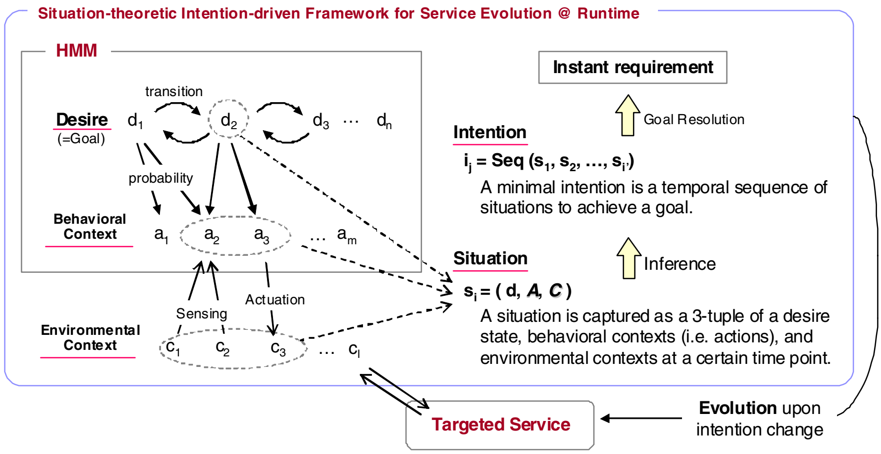

Fig. 1. The Situation-theoretic Framework

for a higher-level formal mechanism to understand human intention change by one of the key components in our situation-theoretic framework. The situation-theoretic framework reflects its nature as an intention driven approach to service evolution. As in [7], we formally define *situation* as follows.

Definition 2.1. *a situation at time t, Situation(t), is a triple* $\{d, \mathbb{A}, \mathbb{C}\}_t$ *in which d is the predicted user's desire,* $\mathbb{A}$ *is a set of the user's actions to achieve d as a goal, and* $\mathbb{C}$ *is a set of context values with respect to a subset of the context variables at time t.* We denote the set of all situations in the system as *Situ*.

Although human intention is intangible, observable actions which are aimed at a desire as a short-term goal show statistical regularity. That is, a sequence of situations generally provides certain information of regularity to characterize an intention. Each process of intention monitoring can only start when its precondition is met (e.g., expected situations), and complete when its postcondition is satisfied. An intention can be defined as a certain sequence of the situations coupled with actions, and formally defined as:

Definition 2.2. *With respect to a goal g, an intention is defined as* $I = seq\ (\ S_k,\ S_{k+1},\ \ldots,\ S_{k+r}\ )$ *that can achieve g, where k and k + r* $(k, r \geq 0)$ *represent the starting point and the ending point of the intention, respectively.* S_i, $i \in \{k, \ldots, k+r\}$, *belongs to the situation set Situ.*

Theoretically, human intentions, including intention changes, should be continuously monitored and inferred at every moment during system runtime; however, it is almost impossible for the current state of the art to achieve this. Even with Definition 2.2, one major issue remains; in the real world, often some irrelevant or intermittent actions are mingled with a sequence of relevant actions to achieve one of an individual's desires. The following definition formulates a *minimal intention* as the sufficient condition to reach a goal.

Definition 2.3. *If a desire d is detected at time t, a minimal intention is an intention* $I = seq\ (S_t, S_{t+1}, \ldots, S_{t+k})$*, where* $k \in N$ *and* $k = \min\{j - 1 \mid j \in N$ *is the length of a sequence of situations, whose starting point is* S_t*.*

These definitions in this section work as the foundation of the situation-theoretic framework to infer human intentions from contexts. For each observation, an intention change occurs if sufficient conditions of an intention is different from the past intentions monitored.

3 Analysis on Smart Home Data

3.1 Experimental Object

The National Institute of Information and Communications Technology (NICT) in Kyoto, Japan pioneered the research in smart homes. NICT researchers constructed a living lab in their facility that incorporated many smart home features. It is essentially a ubiquitous environment where experiments to validate many smart-home theories can be conducted. Networked video cameras and microphones were installed. RFID systems and floor pressure sensors, and 113 switch sensors around every door in the home were equipped to record sensor information from human actions.

In particular, a real life experiment was conducted for 16 days from January 14th to 29th, 2006. The subjects were a couple, husband and wife, in their sixties. They used the smart home as if it were their own apartment. Raw sensor data collected from this experiment are now available to researchers for sharing information and analyses [9].

We analyzed sensor information from the smart home data to discern intentions and observe intention changes. Specifically, situations pertaining to leaving the confines of the smart home (i.e., going through the entrance door) were intensively scrutinized and checked for safety concerns of the residents; depending on the intention of a resident, some situations can be incorrectly interpreted by the smart home system as perilous, such as going out without returning after an elapsed time period (i.e. out-of-bound per safety threshold). In this analysis, theree intentions (taking garbage out, eating out, and eating at home) were monitored to judge the purpose of going out. We discuss the differences and similarities between the three intentions in the following section.

3.2 Intentions of Smart Home Residents

In the smart home, residents went outdoors to put their garbage in a trash can for a total of 19 times in 16 days. The action of taking garbage out (i.e., from opening and closing the door while standing on floor-pressure sensors at the entrance) required at most 62 seconds according to the historical data. The residents passed by a trash box area every time before taking the garbage out. Table 1 shows the sequence of situations. For identifying the intention, the following two situations were collected.

Intention 1. Taking garbage out
Desire: To keep home clean
Seq. of situations: (a) Moving within trash box area, (b) Staying out
Context variables: time, footpath, entrance door (open/close), duration of staying out

Table 1. Taking Garbage Out

Date	Context Variables	7:26:52	7:26:58	7:29:30	7:30:25
Jan. 14, 2006	*Situation*	Moving within trash box area		Staying out	
	Action	Moving	Moving	Going out	Coming back to home
	Footpath	In trash box area (x, y) = (360, 1440)	Out of trash box area (x, y) = (540, 2520)	Entrance (x, y) = (3780, 2160)	Entrance (x, y) = (3960, 1800)
	Entrance door	-	-	Open	Close
	Duration of Staying Out	-	-	0 sec	55 sec

Both of the two situations use footpath as the context value. The trash box area was defined in a square range. In this case, the wife moved within the trash box area for 6 seconds, and then went out for taking her garbage out. This intention is relatively simpler to find than others are.

However, with the same situation "staying out", residents may have different intentions. Sometimes the residents went out for lunch after moving within the trash box area. For eating out, they spent at least 51 minutes. This intention to eat out includes the following situations:

Intention 2. Eating out
Desire: To have a meal
Seq. of situations: (a) no lunch at home (i.e., $'eating' \notin A$ in the situation), (b) staying out
Context variables: time, refrigerator door (open/close), kitchen cabinets or shelves (open/close), entrance door (open/close), RFID tags, duration of staying out

Table 2. Eating Out

Date	Context Variables	11:43:41	11:43:41 - 11:57:57	11:57:57	18:07:35
Jan. 28, 2006	*Situation*	No lunch at home		Staying out	
	Action	Opening refrigerator door	No eating	Going out	Coming back to home
	Refrigerator door	Opened (Switch No. 18146)	-	-	-
	Kitchen cabinet / shelf	Never opened from 9:35AM		-	-
	RFID	Husband in the kitchen and Wife in the living room	Husband and Wife in the home	No one in the home	
	Duration of Staying Out		-		6 hours 9 min. 38 sec.

In Table 2, duration of staying out is one of the differences between intention 1 and intention 2 because intention 1 (taking garbage out) had never taken longer than 1 minute. For improving detection accuracy, “no lunch at home” was captured as one of the constraints to find intention 2 (eating out); there are only two choices of eating out and eating at home for lunchtime. Intention 3 (eating at home) was also analyzed for judging whether they had lunch in their home.

Intention 3. Eating at home
Desire: To have a meal
Seq. of situations: (a) cooking, (b) having lunch
Context variables: time, footpath, refrigerator door (open/close), kitchen cabinets or shelves (open/close), RFID tags, duration of staying the kitchen

Table 3. Eating at Home

Date	Context Variables	12:13:12	12:18:21	12:19:38	12:27:48
Jan. 28, 2006	*Situation*	Cooking		Having lunch	
	Action	Opening refrigerator door	Opening kitchen cabinet	Eating	Moving
	Footpath	Kitchen area (x, y) = (2520, 1080)	Kitchen area (x, y) = (540, 1440)	Dining table area (x, y) = (1620, 4500)	Out of Dining table area (x, y) = (540, 4320)
	Refrigerator door	Opened (Switch No. 18146)	-	-	-
	Kitchen cabinet / shelf	-	Opened (Switch No. 18135)	-	-
	RFID	Husband and wife are within the area of the kitchen	Wife is in the area of the kitchen. Husband is in the living room.	Husband and wife are within the area of the living room	
	Duration of Staying the Kitchen	6 min. 6 sec.	11 min. 15 sec.		-

This intention was inferred by satisfying $seq('cooking', 'havinglunch')$. The situation of cooking was characterized by the window of observation: duration of staying the kitchen, as well as opening and closing of the refrigerator, kitchen caninets, or shelves. The time threshold for such activities was 2 min. 24 sec. (average time between cooking and walking through the kitchen). The situation of having lunch was captured when both husband and wife were within the area of dining table. These are the most likelihood situations from the given context variables. An exception was the case that some guests were invited to the kitchen and the wife made tea.

Intention 2 is a result of intention change from Intention 3 by choosing where to have lunch. Both intentions were successfully detected at daily intervals except when the quests entered in the home. However, more sensors to identify human status will be required to improve detection accuracy. In the smart home data, an intention change was found with intention 2. That is, one day the situation of eating at home followed returning home instead of eating out, i.e., $seq('nolunchathome', 'goingout', 'havinglunch')$. In the same way, further intention change is possible when the residents order a delivery service for lunch; only the situation of having lunch is partly the same as intention 2. These changed intentions are potential requirements to develop a new service to warn of dangerous situation or health-damaging behavior.

4 Discussion

Most sensor-based approaches research focus on adaptive accommodating of the user's specific need, and many promising researches use machine learning techniques [5] [10]. However, in most previous research, intentions derived from situations are still *low-level behaviors* [10] (e.g., an intention explains only a temporary goal without the corporate memory) and microscopic (e.g., no end-to-end scenario to relate human goal to human behavior based on the observations over a period of time). Compared to other research, we defined situation and intention in precise terms; in the situation-theoretic framework, intentions are observed in the temporal sequence of situations with respect to a certain desire of an individual service user. Thus, our framework provides system designers with an opportunity to capture human intention with behavioral patterns and to construct instant service requirements.

Definitions of situation have been described from many different perspectives by researchers. For instance, some researchers defined situation as "histories" (i.e., finite sequences of primitive actions [11] — thus corporate memory is maintained), or a set of contexts in a system over a period of time [1] that evolves. Situation can be also reasoned by aggregating a set of predicates that explicitly represent information about sensory data [8]. Sequencing such predicates can form the history of a finite number of instances in the first-in first-out order. The novelty of our study lies with our definition of situation that is semantically richer than the prevailing definitions for context-aware service environments. In our framework, situations perceived by a human depend on the human's internal mental state, and the actions performed can be regarded as an external reflection. Note that context value changes are side effects of human actions that are externally observable. This new definition for situation affords us a high-level computational playground.

This paper addressed only human intention in the smart home, however intention change is often accompanied by particular emotions, such as dissatisfaction with a health state. Thus, affective computing (e.g. non-invasive real-world human affect monitoring system that measures human stress and fatigue [12]) also plays an important role in simultaneously visualizing affective states and corresponding intentions. This technique can help the system detect dangerous states in a timely manner, understand the relevant causes and consequences, and engage in appropriate assistance and alerts accordingly [13]. Our future work will include modeling affective states for further improvement of intention monitoring.

5 Conclusions

This paper presented the situation-theoretic framework with the definitions of situation and intention, and analyzed human intention in a smart home environment. Experimental results from data analysis showed three intentions with five situations. Furthermore, intention changes were detected by checking sequences of situations. In our framework, the well-defined notion of situation helps to capture human thinking and behavior patterns that in turn help developers specify instant service requirements. Our research focus on human intention changes will prove to be useful and timely.

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Multi-purpose Ambient Display System Supporting Various Media Objects

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Abstract. The motivation of this paper is that the previous ambient display systems are focused on photo display or special purpose such as senior care. It is difficult to customize these systems for other purpose. We present multi-purpose ambient display system. The proposed system supports various display hardware, accepts various media objects (images, videos, agents, voices, sounds, and scripts), and uses simple and powerful Scene Description Language (SDL). The proposed system is composed of three parts; first, a scene renderer parses a SDL and renders 3D image on the screen. Second, a display mediator distributes display request to adequate scene renderer. Third, a mobile messenger is communication tool. We evaluate the proposed system in our Activities Daily Living (ADL) monitoring system and medication alert system.

Keywords: ambient display, scene description language, multimedia object.

1 Introduction

The benefit of ambient display system has been discussed in many articles [1][2][3][4][5][6], but most systems are focused on picture, photo display or special purpose display such as senior care. This paper introduces a multi-purpose ambient display system. The characteristics of the proposed system are three. First, we implement ambient display system independently of display size (from 3.7 inch to 40 inch display), display capability (CPU performance, 3D graphics card performance), and connection method (TCP/IP connection or Bluetooth). Second, we accept various media objects such as pictures, photos, videos, sounds, voices, agents, and scripts. These media are synchronized in time domain. Third, we create scene description language (SDL) with XML. It supports time domain synchronization, 3D display, scripting for dynamic scene description. With these characteristics, the proposed system can be used a good ambient display solution in many fields such as senior care display system, home or office information system and digital photo frame and so on.

In this paper, we will discuss our outstanding display system about design, structure and implementation. In chapter 2, we show the system configuration of the proposed system. In chapter 3, a detail description is discussed. In chapter 4, display mediator is discussed. In chapter 5, we show experiment applied into home display for senior. In chapter 6, we will discuss a conclusion.

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2 System Configuration

Overall system is composed of three parts, a scene renderer, a display mediator, a mobile messenger (Figure 1). The scene renderer renders SDL on the screen. The scene renderer can be executed in many different hardware devices such as desktop PC with single or dual display monitor, tablet PC, UMPC, PDA device based on Microsoft Windows XP or CE. Because a display hardware device may have a variety of CPU and 3D graphics performance, the scene renderer makes final scene in consideration of their performance. For example, if target hardware device such as PDA which cannot support 3D graphics, the final scene is made with only 2D graphics. If target hardware device can support Microsoft Shader Model 3.0 [14], the final scene is made with 3D graphics and screen effects are maximized. The mobile messenger is software executed in a PDA. It is similar to Simple Messaging Service (SMS) in

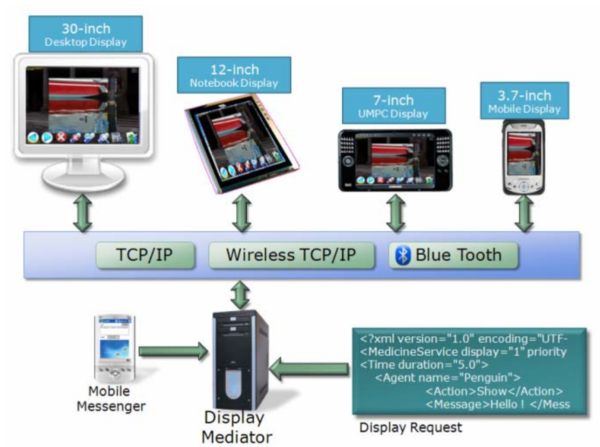


Fig. 1. System configuration: An overall system composed of a display mediator, various scene renderer systems, and mobile messenger

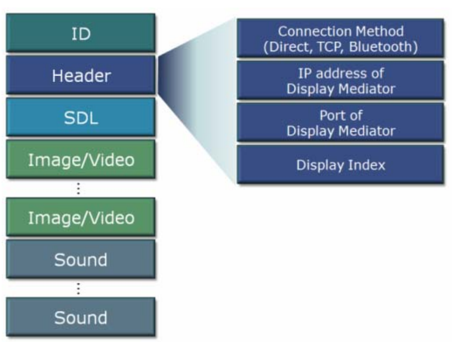


Fig. 2. Format of display request: In header part, display index is placed. SDL, Images, videos and sound files are also included.

cell phone but it can send text message and image simultaneously. The text and image data are sent through H.225 Registration, Admission and Status (RAS) protocol. The display mediator distributes received display request to various scene renderer through TCP/IP, wireless TCP/IP or Bluetooth.

A flow from display request to rendering the scene is as follows. (1) The display mediator receive display request through the Internet or web service. (2) The display mediator finds a display index in the header part of display request and sends it to adequate scene renderer. The format of display request is shown in Figure 2. (3) The scene renderer receives the display request and parses SDL which is third part of display request and then, renders it on the screen.

3 Scene Renderer

The scene renderer parses SDL with XML parser and renders the scene independent of hardware performance. Previously, similar systems are introduced in commercial and research field. Adobe Flash [9] is a multimedia platform and developed by Adobe Systems. Since its introduction in 1996, Flash is commonly used to create animation, advertisements, and various web page components, to integrate video into web pages, and more recently, to develop rich Internet applications [10]. But Flash is focused on manipulating vector and raster graphics and does not support 3D graphics. X3D [7] is the ISO standard XML-based file format for representing 3D computer graphics, the successor to the Virtual Reality Modeling Language (VRML) [8]. X3D standard doesn't include other multimedia data except 3D scene information and is hard to implement because format is very complicated. It also does not support time domain synchronization. Our Scene Render is designed for supporting a variety of multimedia objects including 3D scene and with a simple XML format.

3.1 Design of the SDL

SDL is a core part of the display request and follows Extensible Markup Language (XML) syntax. For describing document type of SDL, we define an XML schema (XSD). An XML schema provides a view of the document type at a relatively high level of abstraction [11]. Figure 3 shows XSD of SDL. A root element of XSD is a DisplayService. The DisplayService element has two child elements; Script element and Time element. In the Script element, a user can write scripting with Microsoft C# language. Time element has a time attribute. The time attribute means when the time element begin to show. The time element has four child elements; an ImageVideo (IV) element, an Agent element, a Voice element, a Sound element. The IV element shows image (picture, photo) and video on the screen. The Agent element controls an agent which is used as a kind of user interface. The voice element lets Text to Speech (TTS) engine to synthesize a voice. The Sound element plays the sound.

3.2 IV Element

The IV element displays image and video files on the screen using Microsoft Direct3D graphics library [12]. Direct3D was developed by Microsoft and provides

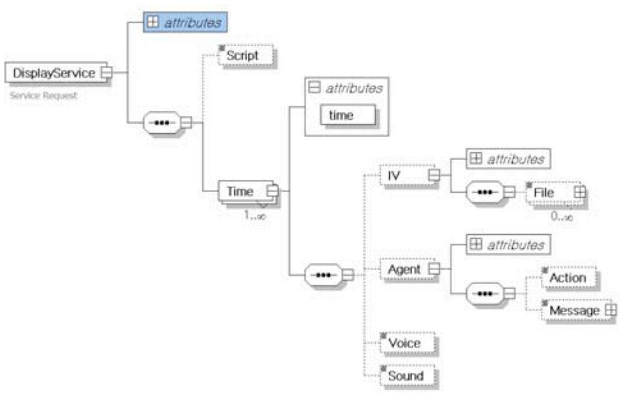
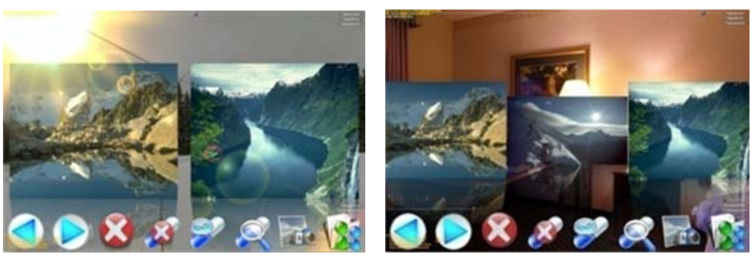


Fig. 3. XML Schema (XSD) of Scene Description Language (SDL)

programmers with a way to develop 3D rendering programs that can utilize whatever graphics acceleration device is installed on a PC. Still image formats such as BMP, JPG, DDS, and PNG are supported. If still image has alpha channel, an alpha channel value is applied. A video file format such as WMV, ASF, and AVI are also supported. If there are two or more File elements in the IV element, two or more files are displayed simultaneously.

When image and video appears or hides on the screen, 3D effects are applied. The effects fall into two categories. First is a transform effect which translates, rotates and scales 3D object. Second is special effect such as wet floor effect, lens flare effect, motion blur effect and so on. Figure 4 shows the result screen of the IV element.



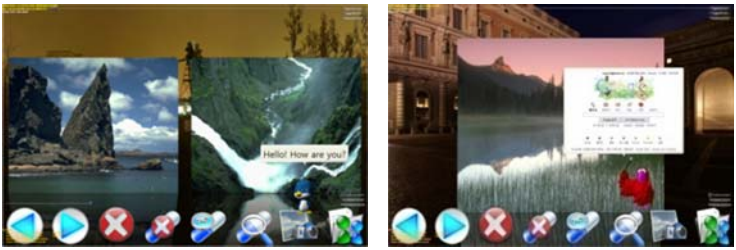
(a) (b)

Fig. 4. Showing IV element: (a) two images are displayed and (b) Two images and one video are displayed

3.3 Agent Element

An agent is a kind of user interface object and helps user to notify alert or alarm. The agent element is similar to the Microsoft Agent [13] but Microsoft agent had not some functions we need. So we fully developed our new agent system. New functions we add are balloon tooltips with web browser and new agent action.

The agent element has two child elements. First is an Action element. The action element is an action which agent animate. The number of actions are 15; Show, Hide, Idle, Greet, Blunder, Good, Mistake, Talk, Alert, PointLeft, PointRight, MoveLeft, MoveRight, MoveUp, and Other action. PointRight and PointLeft is a new action which the Microsoft agent does not have. Second is a Message element. The Message element is displayed in the balloon tooltip. The types of message element are plain text, HTML, URL. Figure 5 shows the agent in a screen.



(a) (b)

Fig. 5. Agent Element: (a) Penguin agent with plain text in a balloon tooltip and (b) Peedy agent with web site in a balloon tooltip

3.4 Voice Element

A voice element synthesizes the voice from text. We use L&H Truevoice Text-to-Speech (TTS) engine.

3.5 Sound Element

This element plays a sound file. Supported formats are WAV, PCM, MP3 and MDI. Eight sound file can be played at the same time.

3.6 Script Element

In the script element, a user can write Microsoft C# language for scripting and control other element dynamically. Because the syntax of script is same as C#, a user can use loop keywords in C# syntax (for, while, foreach), condition keyword (if), variables, functions, and so on. A script element is executed as follows. For example, if some condition (mouse click, mouse enter, and so on) of an element is occurred, a script function which is connected to the element is executed. Each element may have call back function in a script. The number of types of call back condition is six: onStart, onMouseClick, onMouseDown, onMouseUp, onMouseEnter, onMouseLeave.

3.7 Simple Example of SDL

Figure 7 shows simple example of SDL. Its format follows the XSD described in chapter 3.1. The root node is the DisplayService (line 2). The root node has three child elements; Script element (line 3) and two Time elements (line 18, 28). When the scene render execute this SDL, the execution steps are as follows. In line 18, the Time element starts at time 0. In line 20, the File element shows the picture (sunrise.jpg) on the screen and a call back function (onmouseclick=”clickImage”) is attached to the File element. In line 22, the agent Penguin is appeared. In line 26, voice is played. All child elements in a Time element executed at time 0 simultaneously. In line 28, Second time element is executed at time 10 (time unit is second). In line 29, the voice element has an id attribute (id=”voice1”). The id attribute is used for reference in a script.

If a user clicks the mouse button in the picture (sunrise.jpg), a script call back function block, clickImage (From line 9 to line 15) is executed. In line 11, the Voice element with id “voice1” (line 29) is found and assigned to variable voice. In line 12, the text of the Voice element is changed to “New Message Arrived”. If user does not click the picture, the voice element is not changed.

This example simply shows how to execute elements and script. The script can unlimitedly expand the functionality of SDL.

4 Display Mediator

The Display Mediator receives the display request and distributes it to adequate the scene render. The structure of display request is Figure 2. The display request may contains many images/videos and sound files. So, it may have large size about 10 MB. If the display mediator distributes a received form of display request, it is a problem in network traffic and executing low performance display device such as UMPC or mobile PDA. Therefore the display mediator resizes and decorates all images included in the display request. Figure 6 shows an image processing in the display mediator. Original picture is overlapped with decoration frame and then resizing, color correction, making effect is applied.

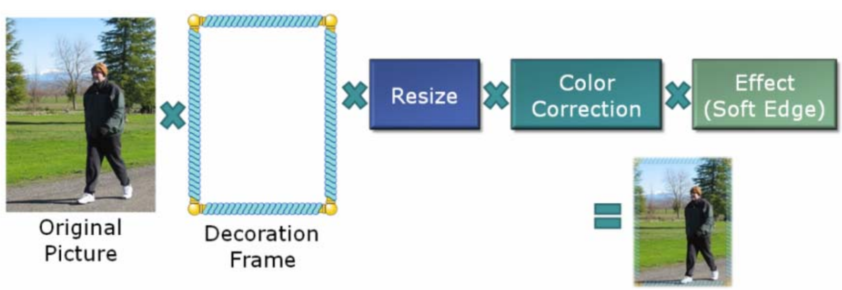


Fig. 6. Image Processing in the Display Mediator

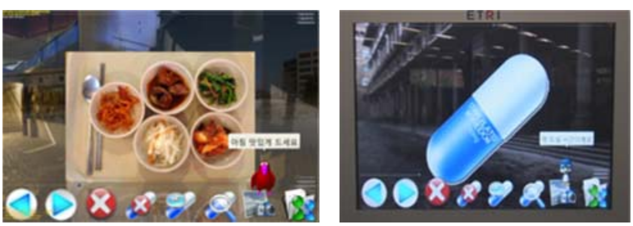
```
<?xml version="1.0" encoding="UTF-16"?>
<DisplayService display="1" priority="1" id="1" repeat="false">
<Script>
   // This is C# script
   using System;
   using System.Windows.Forms;
   using DisplayApp;
   public class CMyScript {
     public static void clickImage(IDisplayApp iDisplayApp , IFile iFile){
         iDisplayApp.Timeline.Pause();
         IVoice voice = (IVoice)iDisplayApp.GetObject("voice1");
         voice.Text = "New Message Arrived";
         MessageBox.Show(voice.Text);
         iDisplayApp.Timeline.Play();
     }
   }   // class
</Script>
<Time time="0.0">
    <IV track="0">
      <File kind ="image" onmouseclick="clickImage">sunrise.jpg</File>
    </IV>
    <Agent name="Penguin">
         <Action>Show</Action>
         <Message>Good morning!</Message>
    </Agent>
    <Voice>Good morning</Voice>
</Time>
<Time time="10.0">
    <Voice id="voice1">Have a good day</Voice>
</Time>
</DisplayService>
```

Fig. 7. Example of Scene Description Language (SDL)

5 Experiment

In this section, we evaluate the proposed system. We make test environment with one living room, one bedroom and a kitchen. Large display (30 inch) is installed in the living room, 12 inch table PC display installed in the bedroom and UMPC is installed in the kitchen.

Services for experiment are focused on caring the senior and patients. We have two type of experiment: (1) Activities of Daily Living (ADL) [15] monitoring system. We develop an ADL monitoring system using FSR sensors and a body-activity sensor with 3-axis accelerometer to monitor ADLs in noninvasive manner and in real-time. This monitoring system classifies 10 activities by using only five FSR array sensors and a single body-activity senor. Among them, seven activities are ADLs. For determined



(a) (b)

Fig. 8. Experiment Service: (a) ADL Monitoring System, (b) Medication Alert System

ADLs, ADL monitoring system make a display request and send it to the display mediator. (2) Medication alert system. A schedule of medications is stored in the medication alert system. When the patient need take a medicine, the medication alert system sends a display request to the display mediator for taking a medicine.

6 Conclusion

In this paper, we have presented a multi-purpose ambient display system supporting various multimedia objects. In order to develop multi-purpose ambient display, we support various display hardware from 30 inch display with desktop PC to 3.7 inch display with PDA. Our system also support various multimedia objects; images, videos, agents, voices, sounds and scripts. The script object written with C# language expands the functionality of SDL. All multimedia objects are described in scene description language and synchronized in time domain. The format of SDL follows XML standard. In the experiments, we test our system in the field of ADL monitoring and medication alert.

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Towards a Task Supporting System with CBR Approach in Smart Home

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Abstract. Smart Home is a hot research area that has gained a lot of attention in recent years. Smart home applications should focus on the inhabitant's goal or task in diverse situations, rather than the various complex devices and services. One of the important issues for Smart Home design is to perceive the environment and assess occurring situations, thus allowing systems to behave intelligently. This paper proposes a context-dependent task approach to manage the pervasive services, the case based reasoning (CBR) method has been adopted and implemented to recognize tasks, enabling task-oriented system design in smart home environments.

Keywords: Context, Task, CBR, Similarity, Smart Home.

1 Introduction

Currently, more and more homes are being connected to Internet, enabling various devices and services. In the future smart homes, the users might face a multitude of devices with complex capabilities, diverse access networks and different multimedia and control services. In order to leverage the capabilities of the networks, devices and services in smart homes and improve the quality of life for families through appropriate and timely assistance, the inhabitants' goal or task needs to be sensed, anticipated and well supported in the smart home environments.

The idea of the task-oriented computing stems from the fact that 'Man is a creature of habit, who always performs activities as a routine'. To support the task-oriented computing paradigm in a pervasive environment such as smart home, a key challenge is to infer the inhabitants' task. In this paper, we propose a task discovering solution using the Case-Based Reasoning (CBR) on the basis of our former context-dependent task model [15].

Our key contributions in this paper include: i). introducing CBR to reason a context-dependent task, ii). presenting the detailed design of case representation, and iii). proposing a similarity-based matching algorithm for reasoning based on prevailing context information.

The rest of this paper is organized as follows: section 2 summarizes the related work in Task Computing (TC) and CBR; in section 3, we describe the design of case representation using our context-dependent task model; section 4 presents the similarity-based

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matching algorithm for CBR to enable situation awareness; section 5 proposes the CBR framework and performance evaluation with experiments; finally section 6 presents the conclusion of this paper.

2 Related Works

In the last decade, a lot of smart home projects have been initiated by research institutes such as the Georgia Tech Aware Home [1], MIT Intelligent Room [2] and Neural Network House [3] at the University of Colorado at Boulder. Context awareness is one of the primary characteristics of future homes. Collecting information from sensors, reasoning based on information from different sources, and adapting applications to different situations are the main steps of context-aware applications.

Nowadays, much work has been done in TC focusing on context-aware task modeling. However, most of them have been centered on the physical aspects of the user context (e.g. number, time, location) and the environment context (device proximity, lighting condition) [4]. This is despite the fact that many authors have long recognized the importance of using the cognitive aspect of the user context (such as users' goals, preferences and emotional state etc.) [5].

Earlier research in the TC area has defined task-driven computing [6] and task computing [7], and demonstrated applications in a computing-oriented environment. These earlier work simply treated a task as merely binding together a set of relevant computing applications (called virtual services) in a hierarchical fashion, with task defined as the top-level virtual service. Unlike these, we regard task as a bridge between the user and the pervasive system.

As for the research about CBR, it can be viewed as a problem solving technique that reuses previous cases and experiences to find a solution to current problems. A group at the University of Salford has appled CBR techniques for fault diagnosis, repair and refurbishment of buildings [8]. Yang & Robertson in Edinburgh are developing a CBR system for interpreting building regulations, a domain reliant upon the concept of precedence [9]. W. J. Yin et al. used a combination of genetic learning approach and case based learning to solve job-shop scheduling problems [10]. Meanwhile, CBR has gained some momentum in the filed of pervasive computing, T. Ma et, al. applied CBR to adapt user preferences in smart homes. The system presented addresses the issue of acquiring initial case by simply observing the settings of a particular user [11], and A. Zimmermann demonstrated how case-based reasoning could be used to generate recommendations for users in a mobile environment. The recommendations were used to augment a museum exhibition with audio information. Kwon and Sadeh [12] applied case-based reasoning to find a pareto agreement between a consumer and seller in comparative shopping. The MyCampus project [13] reports on the use of case-based reasoning to learn a user's context-sensitive message filtering preferences. Benard et al. describes a framework that uses case-based reasoning to identify the most suited action to perform [14].

3 Context-Dependent Task Model

A task model describes tasks that users need to perform in order to achieve a goal when interacting with a pervasive computing system. A task is tightly related to the current context, that is, a task is highly context-dependent and this relationship must be captured in the model definition. This interpretation can for example be suitable for the development of a smart home environment, where complex cognitive tasks (e.g. "to relax at home") serving a user's need and preference are to be performed. Referring to [15], we model tasks and their relations with the idea of the context-dependent task hierarchy, where each task can be further decomposed into a set of sub-tasks (in the case of a composite task), or in the case of atomic task, a set of sequential activities. A task can be described by a union of the following vocabulary:

Task-ID (TI): a unique identifier of a task in a pervasive computing application;
Task-Name (TN): a string to distinguish a task and easy to understand for a user;
Condition (C): a set of context information, specified in the form of parameters.
Priority (Pr): this field denotes the importance and exigency of a task.
Task-Contract (TC): it has two roles: one is to discovery necessary resources and services for the task; the other is to organize and guide the process of executing a task. The detail of TC is further elaborated in [10].

In summary, each task is denoted by a nested 5-tuple as following:
T= (TI, TN, C, Pr, TC).

4 Context-Dependent Task Supporting with CBR

As for a smart home, the researchers can't consider all the situations the users will encounter, thus it's impossible for them to design a complete rule based system. Meanwhile, CBR has its own advantages, as CBR not only reuses previous cases, but also stores new cases for future reference. If no rule in database matches the new case, CBR system will store the new case as a rule. Since the researcher can't envision all situations in smart home in advance, it's difficult to predict an inhabitant's next activity, and thus CBR may be a promising approach for reasoning in smart home environment.

To use CBR for reasoning context-dependent task, we should consider four important issues: case representation, similarity measurement, case retrieval and solution reuse. Due to the space constraint of the paper, we will focus on case representation and similarity measurement.

4.1 Case Representation

Case representation is the first step for CBR. In the filed of CBR, case representation is related not only to knowledge storage but also to knowledge reasoning. According to the topic of the paper, we will use CBR to reason the inhabitant's task, and now, the important question to answer is: What are the common aspects between task contexts in task modeling and cases in case-based reasoning as we want to express the of users' intention? First, a context and a case seem to be similar in their definition as a description of aspects of a situation. Of course, contexts obtain a more punctual sense concerning time and cases on the other hand may also represent entire processes. But the use of attribute-value pairs to organize cases is the most common form of representation [11], and is also a powerful "language" for describing both contexts and task models.

Generally speaking, a case includes some key attributes, as seen in the follows:

Case = (Case ID, Sulution description, Problem description)

Meanwhile, in our task models, the dependent contexts in the vector 'Condition' can be described as:

Task = (Task ID, Task Name, User ID, Location, Time, Temprature, Noise,...)

Thus, to represent case using the contexts in our task models, we can transform the parameters in task model into case components.

Fig.1 illustrates our approach of representing a case by mapping the problem solution pairs of a case description to context-dependent attributes pairs. The problem description complies with the description of the context dependent to a task. As this context description covers the several dimensions as mentioned, the case's problem description is a multi-dimensional vector of complex attributes.

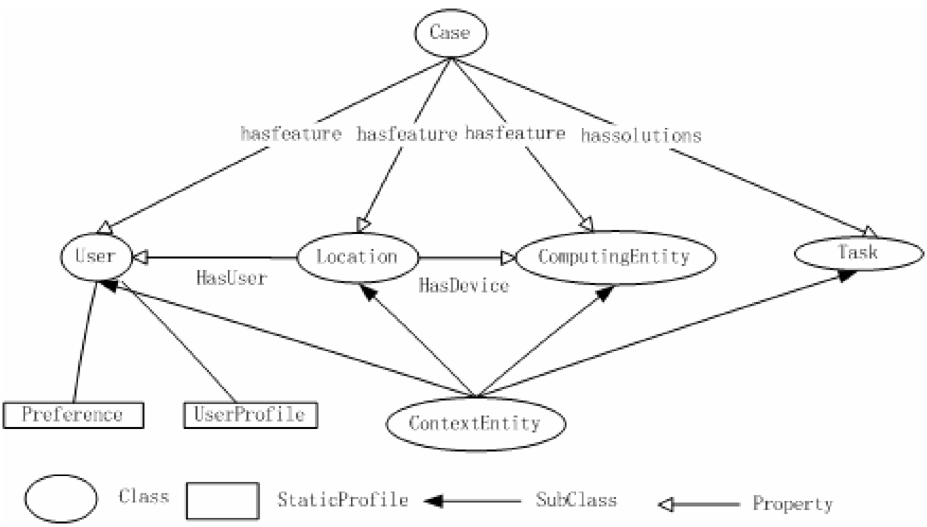


Fig. 1. Case representation with task model using ontology

As shown in Fig. 1, each task has a corresponding case, and such a case can be organized in a table form and stored in a database. In the initial stage, the table consists of some key attributes: such as User ID, Location, Time, etc.. Besides the main attributes, more other attributes can also be added according to the contexts related to a task.

After representing the cases with the contexts, the reasoning procedure is equal to the task inferring with CBR. The structures and properties of context predicates are described in an ontology which may include descriptions of classes, properties and their instances. The ontology is written in OWL as a collection of RDF triples, each statement being in the form (*subject prop, object*), where subject and object are ontology's objects or individuals, and predicate is a property relation defined by the ontology. Table 1 describes the storage of a complete case and related contexts in the database, and this case (CaseID is 142) means that the user (NHB) is executing the Bathing task in the BathRoom_30 at 8:40, and it is stored in the case base with the form of RDF triples, as seen in the Fig. 2.

Table 1. Case representation with RDF tripels

Subject	Prop	Obj
NHB	User_Locatedin	BathRoom_30
NHB	Time	8:40
BathRoom_30	HasDevice	Shower
Shower	Entity_state	On
BathRoom_30	HasDevice	Lamp-2
Lamp-2	Entity_state	On
BathRoom_30	Door-State	Off
NHB	User_Task	Bathing

Resultset 1

CaseId	subj	prop	obj	usedtime
142	Uv::http:...	Uv::ht...	Lv:0:39:http://www.w3.org/2001/...	1
142	Uv::http:...	Uv::ht...	Lv:0:39:http://www.w3.org/2001/...	1
142	Uv::http:...	Uv::ht...	Lv:0:36:http://www.w3.org/2001/...	1
142	Uv::http:...	Uv::ht...	Lv:0:39:http://www.w3.org/2001/...	1
142	Uv::http:...	Uv::ht...	Lv:0:39:http://www.w3.org/2001/...	1
142	Uv::http:...	Uv::ht...	Uv::http://www.owl-ontologies.co...	1

Fig. 2. Case storage with RDF triples in database

4.2 Similarity Measurement

As mentioned in the above section, a case is organized as a table, and each column is equal to a context attribute, and the whole table equals the condition of a task. So, the similarity is defined on two levels: local similarity and global similarity. The generalized distance can be used to estimate similarity.

The key idea is to match the case parameters to the value dynamically aggregated from the environmental and user contexts. Specifically, let us define each Condition to be a context tuple, i.e. C=<c1,c2,…,cn>, c1…cn are a set of context attributes, as well the corresponding parameters in one case table. In an actual system, Context tuple values are sampled periodically. In these tuples, there may be many types of attribute values (both numerical value and Boolean). Each kind of attribute values has its own similarity calculation method, which can be expressed in a general form as follows:

$$dis(v(c_i), v'(c_i)) = \frac{|v(c_i) - v'(c_i)|}{dom(c_i)} \quad (1)$$

where c_i means a context attribute, $v(c_i)$ is an expected value, $v'(c_i)$ is the real-time value, and $dom(c_i)$ means the maximal difference of two values $v(c_i)$, $v'(c_i)$. Obviously, for any attribute c_i , the value $dis(v(c_i), v'(c_i))$ is within[0,1].

The table (Condition vector) similarity is the combination of all evaluated attribute similarities, and we can revise the typical distance formula to measure the table distance.

$$\text{Manhattan Distance: } dis(T(c), T'(c)) = \sum_{i=1}^{n} \left| \frac{v(c_i) - v'(c_i)}{dom(c_i)} \right| \quad (2)$$

Here, each attribute has the equal contribution for the similarity, in fact, we should further take into consideration that diverse attributes have different contribution to the Condition's overall similarity, and an *attribute weight* is used for this purpose, for example, location, and time can have a higher weight than others. So the overall similarity can be evaluated as follows:

$$dis(T(c), T'(c)) = \sum_{j} wjdis(v(cj), v'(cj)) \quad (3)$$

where $\sum_{j=1} wj = 1$. The range of $dis(T(c), T'(c))$ is [0,1], a value of zero means perfect match and 1meaning complete mismatch.

For example, we can define a 'noon break' task as following:

NoonBreak_Task= (Task_1122, NoonBreak, User_Ni, InBed, Noon, Door_Closed)

As to this task, the corresponding contexts includes: user location, time and the status of the door. Specifically, we can detect the user location with pressure sensor on the mattress, and the time will be provided by the system clock, and the status of the door is checked by the angle sensor on the top of the door. Assume that the user sleeps in the bed at 12:15 with the door left unlocked, we can calculate several contexts with diverse method as following Table 2.

Table 2. context similarity calculating in the Noonbreak-task

Property	Detecting Method	Default Weight	Similarity
Location	number of activated/total (30)	0.466	2030=0.667
Time	real time in [12:00-13:30]	0.277	1 (time = 12:15)
Door_Status	detected angle/180	0.257	120/180

The overall similarity can be calculated with the equation (3), i.e. 0.466*0.667+ 0.277*1+0.257*0.67=0.76, so we can infer the probability of the Noonbreak task is 76%, that is, the user is likely sleeping in the bed for noon-break.

5 System Framework and Performance Evaluation

To integrate CBR in our context-dependent task supporting system, we have designed a CBR-based reasoning sub-system (as seen in Fig. 3), which is to discover a context-dependent task in a smart home. In CBR sub-system, the original context data, such as time, location, and temperature is generated by sensors, and then sent to the case representation module. After structured, the real-time context data is filtered into the case table, and the similarity can be calculated between the real-time case and template case from the task-base. The best match case is retrieved from task-base database, that is, the result is the inhabitant's task.

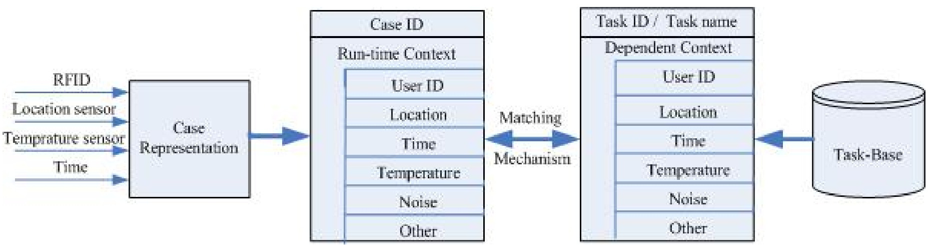
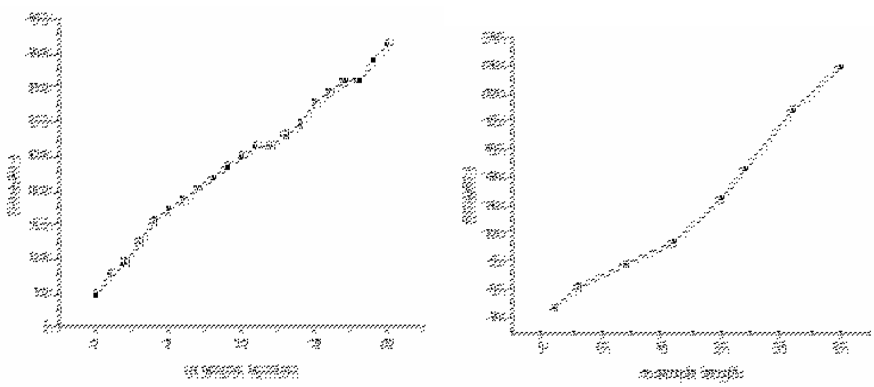


Fig. 3. CBR sub-system Framework

According to the use scenarios in a smart home, we have conducted the experiments on a windows XP platforms, the system configuration is: CPU: P4-2.4G, RAM: 512Mb, IDE: Eclipse3.0.1 +JDK1.4.2. we applied the Protégé + MySql to compile and store the context data, and the experiment results are as follows:



(a) (b)

Fig. 4. The experiments result of CBR reasoning

As can be seen in Fig. 4 (a), the size of case is the key factor for the system performance, and the minimum time is 78ms (for one case), the maximum time is 415ms(for 20 cases). Since we have classified the cases into 6 types according to the user place, there will not be too many cases in a specific location, so we think the performance of the reasoning system is acceptable in smart home environment. Furthermore, as can be seen in Fig. 4 (b), the dimension of attributes is another important factor, and the matching duration is proportional to the size of case and the number of attributes.

6 Conclusions

This paper proposed a CBR-based context-dependent task discovering solution. We discussed the approach of case representation, the similarity measurement algorithm, and the method for transforming task contexts into case attributes. Furthermore, we presented the CBR sub-system framework and showed the evaluation results. We are currently evaluating the proposed reasoning approach for elderly care applications in a smart-home environment, and we will report our progress in the near future.

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Appliance Recognition from Electric Current Signals for Information-Energy Integrated Network in Home Environments

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Abstract. We are developing a novel home network system based upon the integration of information and energy. The system aims to analyze user behavior with a power-sensing network and provide various life-support services to manage power and electric appliances according to user behavior and preferences. This paper describes an electric appliance recognition method using power-sensing data measured by **CECU** (**C**ommunication and **E**nergy **C**are **U**nit) which is an intelligent outlet with voltage and current sensors to integrate legacy appliances (which are incompatible with a communications network) with the home network. Furthermore, we demonstrate a prototype home energy management system and examples of services based upon appliance recognition.

Keywords: Home Energy Management System (HEMS), Home Network, Power Sensing Network, Appliance Recognition.

1 Introduction

We propose a novel home network system which integrates information and power networks[1], which we call the Bit-Watt system. Our system aims to manage the energy and electrical appliances in home environments by using ICT (**I**nformation and **C**ommunications **T**echnologies) to provide assertive services, such as home energy management, home safety and health-care, according to user behavior and preferences estimated from power consumption and the state of appliances in home environments. For this purpose, the system requires a framework for collecting information on the appliances and controlling their states.

Recently, intelligent appliances and home networks have been made available commercially, making it possible to monitor and control appliances remotely. The HAVi[2,3] and DLNA[4] have been proposed for IT appliances and audio-visual appliances, and ECHONET[5] is a protocol for home appliances.

M. Mokhtari et al. (Eds.): ICOST 2009, LNCS 5597, pp. 150–157, 2009.

Presently, to use a home network, appliances have to be implemented with these protocol-stacks. In other words, when a user uses legacy appliances in his/her home, the user has to modify the appliances or buy new appliances instead. Furthermore, it is sometimes difficult to implement the protocols for some simple appliances because of size and cost limitations.

To solve these problems, we propose **CECU** (**C**ommunication and **E**nergy **C**are **U**nit) and an appliance recognition method by using **CECU**. **CECU** is an intelligent outlet with voltage and current sensors, a power control circuit for appliances, and a network module. It can measure the voltage and current values; our system recognizes appliances plugged into **CECU** from measured the voltage and current values. In our system, the legacy appliances can be integrated into the home network without any modifications.

This paper describes an appliance recognition method by using **CECU** as the basis of an information-energy integrated network system. Furthermore, we demonstrate a prototype home energy management system as an application of our system.

2 Bit-Watt System: Information-Energy Integrated Network System

2.1 Overview of the Bit-Watt System

Figure 1 shows an overview of the information-energy integrated network system, which we call the Bit-Watt system. The Bit-Watt system consists of **CECU**s, a home server, and a UI controller. **CECU** is attached between the home outlet and appliances, measures the voltage and current values of the attached appliance, and sends them to the home server. It can control an appliance according to commands from the home server. The home server collects power information on the appliances from **CECU**s to identify them and their status. The home

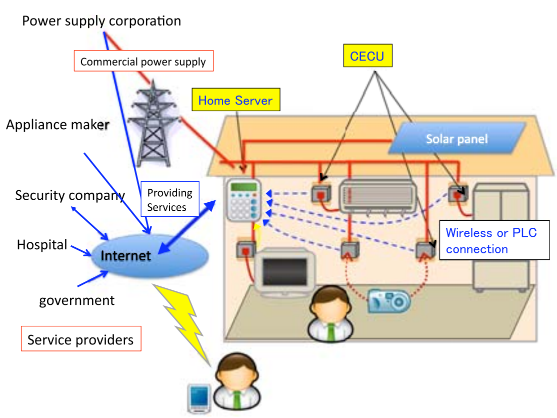


Fig. 1. Bit-Watt System

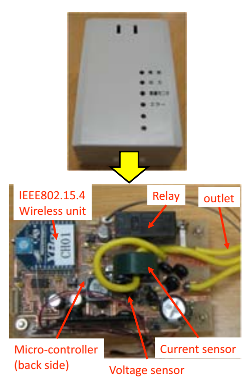


Fig. 2. CECU

server provides services to the user by managing the appliances based upon the collected information.

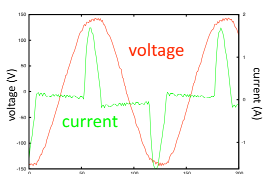
By attaching **CECU** and the home server into home environments, our system can integrate an information network and energy network without remodeling existing appliances and home environments. Furthermore, the home server can connect to the Internet as a home gateway and cooperate with service providers. For examples, security companies can provide home safety services, hospitals can province health care services and appliance makers can provide the appliance information for appliance recognition and detecting broken appliances.

Figure 2 shows a prototype of **CECU**. The prototype includes a voltage sensor, a current sensor, a relay circuit, and a micro-controller. The micro-controller functions to convert analog signals from the sensors to digital values, extract signal features, and control the relay. **CECU** connects with the home server via IEEE802.15.4 wireless connection (like ZigBee[6]). Other wireless technologies or power line communication (PLC)[7] can also be used for the connection between **CECU** and the home server.

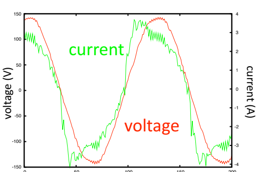
2.2 Feature Extraction for Appliance Recognition

Since home power-lines use alternating current (AC), the voltage and current take wave-shape signals. We believe that the appliance can be identified through comparing features of the shape because they are different for each appliance, as shown in Fig. 3.

However, it is difficult to incorporate recognition processes into **CECU** because of size and cost limitations. On the other hand, it is also difficult to directly send voltage and current values to the home server because a large amount of data is required for shape comparison.



(a) LCD monitor



(b) micro-wave oven

Fig. 3. Examples of the voltage and current signals

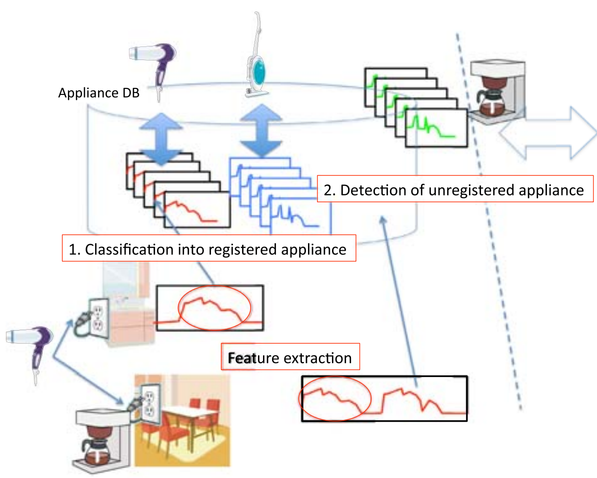


Fig. 4. Appliance Recognition

To solve this problem, we implemented the recognition process as cooperation between **CECU** and the home server. **CECU** extracts a few features from the measured voltage and current values, and the home server recognizes the appliance from these features by comparing them with an appliance-feature database.

Here, the features should be small in number and easy to extract via the micro-controller in **CECU**. We consider sampled values for the electric current of each AC cycle as a high-dimensional vector and extract features through dimension reduction techniques using principal component analysis (PCA).

In the learning process, training vectors of electric current signals are given for all target appliances in advance, and eigenvectors are calculated by PCA from these training vectors. Then, a few eigenvectors with the maximum eigenvalues are selected as basis vectors for feature extraction.

During the recognition process, **CECU** extracts features with an inner product between the input vector of the current signal and basis vectors and sends them to the home server. Furthermore, training and input vectors are normalized by the root mean square of the vectors to eliminate changes in the wave-shape caused by differing loads of appliances.

Concrete processes for feature extraction in **CECU** are implemented as follows.

Let S be the sample number of voltage/current signals for each AC cycle, K be the dimension of extracted features, and $\mathbf{e}_j = \{e_{j,1}, \cdots, e_{j,S}\}$ be the j-th eigenvector. The eigenvectors $\mathbf{e}_0, \mathbf{e}_1, \cdots, \mathbf{e}_{K-1}$ are stored to a table in the micro-controller in advance.

1. Wait until zero-crossing of the voltage signal is detected.
2. Define the sampling counter $s := 1$, sum of squared current values $I_{SS} := 0$ and features $f_j := 0 (j = 1, \cdots, K)$
3. Sample the voltage value $v(s)$ and current value $i(s)$.
4. $I_{SS} := I_{SS} + i^2(s); f_i := f_i + i(s)e_{j,s} (j = 1, \cdots, K)$
5. If $s < S$ then $s := s + 1$ and go to Step 3; otherwise, go to Step 6.
6. Send I_{SS} and $f_j (j = 1, \cdots, K)$ to the home server and go to Step 1.

Since this process requires simple sum-of-product operations only by **CECU**, it can be quickly calculated by the micro-controller. Furthermore,the process can be implemented as an exclusive logical circuit. Even in this case, the feature can be modified by updating the basis vectors table.

The home server calculates the root-mean-square of the current values $I_{RMS} = \sqrt{\frac{I_{SS}}{K}}$ and normalized features $\hat{f}_i = \frac{f_i}{|\mathbf{e}_i| I_{RMS}} (i = 1, \cdots, K)$ from when it receives f_i and I_{SS} from **CECU**.

2.3 Appliance Recognition for Bit-Watt System

Figure 4 shows an overview of the appliance recognition process. In this process, **CECU** measures the current signal of the appliance plugged into its outlet, extracts features from the measured signal in an AC cycle, and sends it to the home server. The home server recognizes the appliance by comparing the measured features with registered features in the database.

However, it is difficult to register the features for all the different kinds of existing appliances into the the home server database in advance. To solve this problem, the system registers the features as a new appliance when it detects the features of an unregistered appliance. We assume that the features and information of the new appliance can be downloaded from web sites of the appliance maker or service providers for the appliance data via the Internet. The system requires two types of recognition techniques: classification of registered appliances and detection of unregistered appliances. We used a support vector machine (SVM) [8] with a Gaussian kernel for the classification process and a one-class SVM [9] for the detection process. The one-class SVM is an extension of SVM for one-class classification problems, which is classifying an input pattern into a registered cluster or not.

3 Evaluation of Appliance Recognition

In this section, we show the experimental results of the two types of recognition processes; classification of registered appliances and detection of unregistered appliances.

3.1 Experimental Environment

Table 1 shows information of the target appliances, name, effective power $P(W)$, apparent power $S(VA)$ and power factor F. We used 25 appliances for the evaluation. The table shows the name and power consumption for each appliance. Appliances with the same name but different number, such as LCD TV 1 and 2, indicate the same kind of appliances but different products. It is difficult to classify the appliances using typical AC parameters, effective power, apparent power and power factor, because some appliances have similar parameters.

Table 1. Target Appliances

	Name	$P(W)$	$S(VA)$	F		Name	$P(W)$	$S(VA)$	F
1	CRT TV	41.0	66.0	0.62	14	refrigerator 1	98.0	134.8	0.72
2	DVD Player	17.4	25.3	0.68	15	refrigerator 2	101.4	129.2	0.78
3	HDD Recorder	40.9	59.5	0.68	16	desk fan 1	12.8	15.1	0.84
4	LCD TV 1	44.1	60.8	0.72	17	desk fan 2	28.9	38.0	0.76
5	LCD TV 2	136.1	141.0	0.96	18	iron 1	1134.3	1169.1	0.97
6	PC	23.6	36.6	0.64	19	iron 2	427.6	448.3	0.95
7	air conditioner	490.9	567.8	0.86	20	washing machine	115.6	123.0	0.93
8	cleaner 1	883.7	908.6	0.97	21	incandescent lamp	26.3	41.4	0.63
9	cleaner 2	186.1	455.6	0.40	22	microwave oven 1	1032.7	1078.9	0.95
10	rice cooker	246.4	248.8	0.99	23	microwave oven 2	733.1	750.7	0.97
11	dryer 1	428.4	476.2	0.89	24	pot 1	1110.8	1135.6	0.97
12	dryer 2	1244.2	1276.1	0.97	25	pot 2	733.1	750.7	0.97
13	dryer 3	774.6	798.7	0.96					

Table 2. Comparison of the classification results

	typical features	original vectors	proposed
16 types	85.5%	99.9%	99.9%
25 products	78.0%	95.6%	95.8%

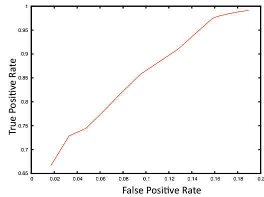


Fig. 5. ROC curve

In the experiments, we used 100 samples of training data and 450 samples of test data for each appliance. The total number of training data was $25 \times 100 = 2500$ and the number of test data was $25 \times 450 = 11250$. The test data were different from the training data.

During the learning process, the eigenvectors and eigenvalues were calculated from all training data by PCA and 4 eigenvectors with maximum eigenvalues were selected as basis vectors. The features for each training vector were extracted by the inner product between each training vector and the basis vectors and the SVM was trained from the features of the training data.

The basis vectors were written into the micro-controller in **CECU** in advance. During the recognition process, the features were extracted by **CECU** using the inner product between the input vector and basis vectors. The extracted features were sent to and recognized by the home server.

A PC with Intel Core2 3.0GHz was used as the home server, and PIC18F2550 was used for **CECU**. The sampling rate of the voltage and current values was set to 100 for each cycle. This means $60 \times 100 = 6000$ samples per second.

3.2 Classification of Registered Appliances

Table 2 shows the classification results for the registered appliances. We evaluated the proposed method by comparing results with using 100 original dimensional vectors or 5 typical features of the alternating current system. The 100 original dimensional vectors are sample current values within an AC cycle, and the 5 typical features include the average value of the electric current, peak to average ratio, phase shifting time, available power time within an AC cycle, and peak delay from the start of the current.

We can see that the proposed method achieved an accuracy of 99.9% for 16 types of appliances and 95.8% for the 25 appliances respectively. This is more accurate than using typical AC features and nearly equivalent to the results of using the 100 original dimensional vectors.

Furthermore, during this experiment, the micro-controller performed the feature extraction within an AC cycle (1/60 seconds).

3.3 Detection of Unregistered Appliances

Here we show the results of detecting unregistered appliances. In this experiment, one-class SVM was trained from training vectors for 24 appliances, excluding one appliance to act as an unregistered appliance. The results were obtained by detecting the unregistered appliance from test vectors while changing the unregistered appliance. Figure 5 shows the detection results as an ROC curve, which indicates false positive and true negative rates while changing the parameters of one-class SVM. The results show that the detection accuracy for unregistered appliances can be optimized by setting the good parameters for one-class SVM. In the best case, the total detection rate achieved an accuracy of 97.7%.

4 Home Energy Management Based on Appliance Recognition

We implemented a prototype to demonstrate the applications of the Bit-Watt system. Figure 6 shows the overview of the prototype Bit-Watt system. It includes **CECU**s, a home server, and some interaction devices.

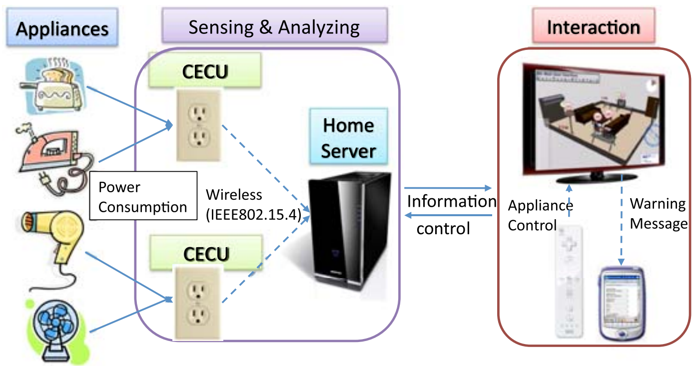
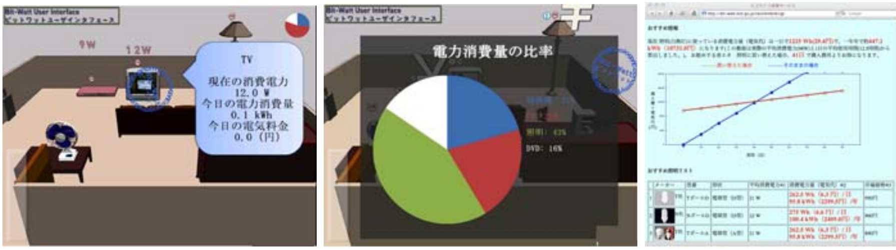


Fig. 6. A prototype Bit-Watt system

The system provides three services with appliance recognition. The first service is watching over and notification for appliances that users forget to turn off. The second service is remote monitoring and control, which provides the status and power consumption for each appliance to the user and control of the appliance via living room interaction devices that consist of a display and Wii®Remote. The third service is recommendation, which recommends new ecology replacements for appliances with wasting power consumption.

Additionally, the system was demonstrated to the public at the ATR/NICT Open House 2008. During the demonstration, we noted the public response that the Bit-Watt system can make users improved the awareness of the wasted power consumptions.

Figure 7 shows examples of the service results. The system could identify the same appliances even if the appliance connects to different outlets. Therefore, the system could accumulate the total amount of power consumption for each appliance even if the appliance location changed. In addition, the system could



(a) monitoring (detail) (b) monitoring (total) (c) recommendation

Fig. 7. Examples of services on the Bit-Watt system

recommend to replace the inefficient appliance with the new ecology appliance as well as the system. Furthermore, the system warned the user against irregular overuse of the appliance.

5 Conclusions

In this paper, we proposed an appliance recognition method using electric current signals for an information-energy integrated network, and we demonstrated home energy management based upon the proposed system.

We extracted appliance features in **CECU** by PCA and recognized appliances from the features by using SVM. In experiments, we evaluated the proposed method and can confirm that the proposed method achieves accurate classification rate.

For future work, we are considering the development of a framework to register features and information on unregistered appliances when they are detected. Furthermore, we are looking into learning user behavior and preferences from measured power consumptions and the state of the appliances in order to develop assistive services for proactive energy management.

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WIVA: WSN Monitoring Framework Based on 3D Visualization and Augmented Reality in Mobile Devices

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Abstract. Research on structural health monitoring (SHM) is gaining importance recently due to increase in industrial accidents at construction sites. Wireless sensor networks (WSN) are considered as the promising advanced SHM technology to provide real time site applications using SHM. In this paper, we propose the WIVA (WSN Monitoring Framework based on 3D Visualization and Augmented Reality in Mobile Devices) architecture. The proposed architecture applies 3D visualization and AR technology to camera enabled mobile devices in order to provide real time information to users. Moreover, we performed an experiment to validate the effectiveness of 3D and AR mode based WIVA architecture in IEEE 802.15.4-based WSN. In a real implementation scenario, we demonstrated a fire detection test in a 3-story building miniature.

Keywords: Wireless Sensor Network, 3D Visualization, Augmented Reality, SHM.

1 Introduction

These days construction industry is trying to hold a competitive edge in technology and management systems. As one of these efforts, it is attempting Intelligent Building (IB) construction through convergence with IT technologies. IB has to maximize productivity continuously within pleasant office environment and raise safety and reliability for humans and buildings. It has to pursue economic efficiency in construction and maintenance side.

Recently, a variety of research for Structural Health Monitoring (SHM) is progressing according to the high-raised and large-sized trends of main building construction. One of the most representative technologies for SHM is wireless sensor networks (WSNs) [1]-[4]. WSN consists of a variety of sensors using a very small size and low electric power, RF communication module, and ad-hoc networking capability [10] [11]. WSNs are usually applied to collect various data of external ecosystem, military system, indoor/outdoor of building, and so on. In order to utilize collected data from sensor networks, it provides a kind of processing functions that analyze information and recognize situation by using various visualization software [12]. In previous researches, 2D-based-monitoring software and network cameras are used in WSN technology for SHM. However, it is required to provide more effective and realistic

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visualization technologies than the existing SHM using WSN since dead angle areas appear frequently. Thus, in this paper, we apply 3D visualization and AR technology to IEEE 802.15.4-based wireless sensor network using various mobile devices. The proposed system is called WIVA (WSN Monitoring Framework based on 3D Visualization and Augmented Reality in Mobile Devices) which provides efficient and convenient user interfaces and capabilities.

The rest of the paper is organized as follows: Section 2 talks about related work. Section 3 describes the framework and architecture of proposed WIVA. Section 4 presents experimental analysis and implementation results. Finally, section 5 concludes this paper and provides a future outlook.

2 Related Works

Recently, construction industry is looking for increase in the productivity and decrease of the project costs. But the accident ratio is increasing in trying to achieve quick completion and increase in productivity. Construction industry is looking for innovation to resolve this issue while keeping the productivity, project cost and deadlines.

To prevent increasing accidents in construction site, research for convergence with various technologies have been gaining in importance. A variety of SHM applications using wireless sensor networks data are introduced. Studies and experiments for convergence with various devices such as smart phone, UMPC to building, underground, and structural site also have been researched. For instance, Hong Kong University deployed sensor nodes for an experiment of SASA (Structure -Aware Self-Adaptive) system as shown in left of Fig. 1 [9]. SASA system is WSNs framework that can detect collapse in the advance, and measure gas, water, oxygen, etc. through monitoring for underground cave structure of coal mining. The one on the right is the 18-story building demonstration model on shaking table that uses Mica2 MOTE for distributed sensing in WSNs environment at Illinois University.

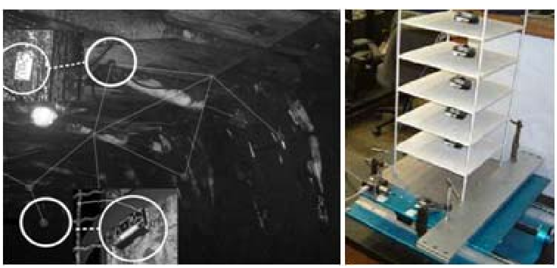

Fig. 1. SASA of Hong Kong Univ. (Left) and 18-stroy building on shaking table of Illinois Univ. (right)

It is a representative technology of SHM that uses application which offers 2D based user interface or sensor surrounding using network camera. In the case of 2D, since description of sensor networks information is not smooth, there are disadvantages such as difference, unreal interfaces for description of real life. On the other

Fig. 2. AR system of Malaga Univ.(left) and Canoga Park of Berkeley Univ.(right)

side, in the most case of using network camera, if sensor devices are located to dead angle areas where camera can't capture it such as area of wall back space etc. or area where eyes can see, we can't know situation information surrounding sensor devices. Left of Fig. 2 is a research, which is proposed by Malaga University, for technique that can deliver sensed information which uses acquisition data from deployed sensors by AR in hospital more easily [6]. The right one of Fig. 2 illustrates a research for vibration aftereffect of building 'Canoga Park' of Berkeley University which is expressed by 3-Dimension to analyze SHM's information more easily [8].

3 WIVA Framework

We propose mobile monitoring framework that AR and 3D visualization technologies are applied. As we mentioned in Section II, the previous researches had problems that couldn’t visualize with 2D based or camera for dead angle areas efficiently. To solve these problems, we propose WIVA (WSN Monitoring Framework based on 3D Visualization and Augmented Reality in Mobile Devices) architecture system which can transmit more realistic information than previous 2D based visualization technologies. Therefore, we also implemented 3D visualization for sensor information on camera image using AR of WIVA system.

WIVA framework architecture is composed of (a) External Module, (b) Core Module, and (c) Internal Module as shown in Fig. 3. External module consists of Serial Management(SM) that performs processing sensed data from sensor nodes, Camera Management (CM) for image processing in AR application which is received from camera.

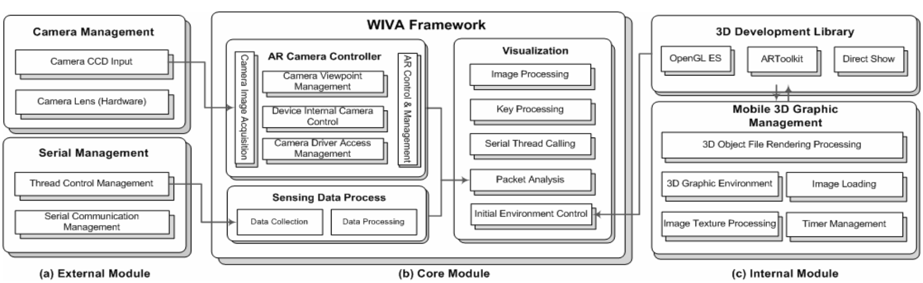

Fig. 3. WIVA Framework architecture

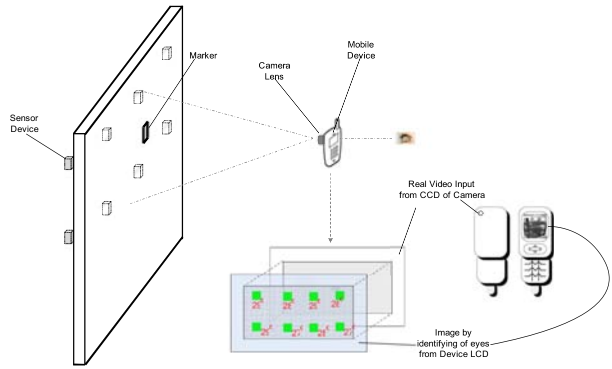

Fig. 4. Application Design of Augmented Reality

Internal module consists of 3D Development Library (3DL) and Mobile 3D Graphic Management (M3GM). 3DL is a library package, and M3GM is for supporting of development environment for 3D modeling using 3DL. M3GM and 3DL loads 3D virtual models of target object such as building, bridge, etc. into application of mobile devices. 3D virtual models are created by specialized tool.

Finally, Core module comprises of three components - AR Camera Controller (ACC), Sensing Data Process (SDP), and Visualization. ACC takes care of management for adjustment and revision of camera images related with AR, as well as calculation for Matrix. SDP takes care of management and processing for raw packet data which is collected from sensor networks. Visualization component takes care of loading image data and execution of 3D and AR mode from ACC and SDP. It is also responsible for visualization of sensed data and images to screen on LCD of mobile devices.

3.1 3D and AR Mode Application Scenario

The system can be operated in two modes. One is 3D mode and the other is AR mode. 3D mode is for confirmation of whole structure status using 3D modeling based on WSNs. AR mode is executed when mobile device users want to view and analyze detail sensor information for dead angle areas.

- Scenario I (3D Mode): 3D mode is executed when mobile device users want to analyze whole target object structure. This mode is a possible method for monitoring through 3D modeling for situation information and structures for target object using mobile application on mobile devices. This mode is executed as following: First, we made 3D virtual model for target object using 3D tools. We can then load and use these 3D models in applications for monitoring even though we are far away from target objects. The sensed data (temperature, moisture…) that is received in real time through dongle is analyzed for anomaly information and is shown on the mobile.

- Scenario II (AR Mode): When mobile device users want to observe detail information about the inside of buildings, AR mode is executed. In case of using AR mode in WIVA, we can see sensor information by 3D model override with real image on LCD

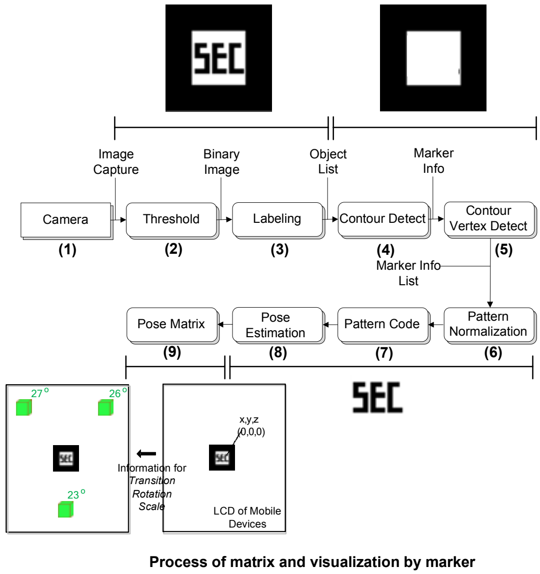

Fig. 5. 3D Visualization process by marker

of mobile devices using captured by camera lens. Fig. 4 describes all procedures for operation of AR mode. If we want to recognize aspect for dead angle areas which are blocked by obstacles such as back of wall, we can play our mobile devices to marker on the wall for AR using a camera. Now, application sensor data which we can NOT see through our eyes are visualized to 3D modeling on LCD screen, and then we can see information by effect as permeated wall. To transmit information more realistic and properly, we have to arrange 3D models of sensor nodes on LCD of mobile devices when we look at the marker using camera of mobile devices. The matrix is pre-calculated by marker as criterion to position exact location for this purpose. Fig. 5 shows the complete process for 3D modeling visualization on camera images by these matrixes. We used the ARToolkit for implementation of Augmented Reality. Each process performs the following functions:

- **Camera (1):** a process for capturing of images from camera. (Images mean an original status for which no process will be applied.)
- **Threshold (2):** a process for transformation from RGB to Gray scale, and then making Binary Image either value is a higher to white (255) or to black (0) using brightness value.
- **Labeling (3):** a process for image processing of building lump parts as one group for white areas in Binary images.
- **Contour Detect (4):** a process for extraction of outline of a group through Labeling.
- **Contour Vertex Detect (5):** a process for finding vertexes of outline. - We can separate square area of pattern marker using this procedure.
- **Pattern Normalization (6):** a process for making Contour as a regular square which has four equal sides and four angles and accomplishes 90 degrees by normalization.
- **Pattern Code (7):** a process for extraction of pattern from square region.

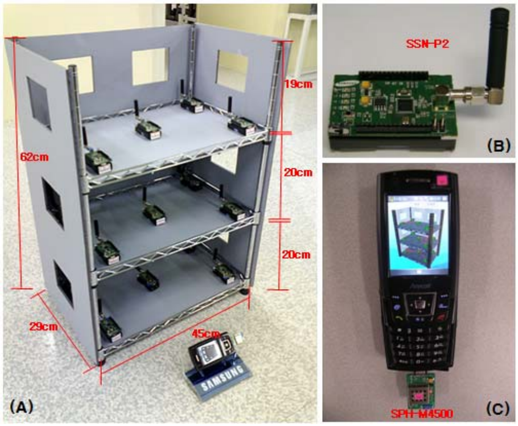

Fig. 6. Our Experiments Environment

- Pose Estimation (8): a process for calculation of Transform-Matrix and Pose-Matrix by estimation S (scale), T (transition), R (rotation) values of pattern marker after comparing detected pattern with extracted pattern.
- Pose Matrix (9): a process for criterions definition of transition, rotation, and scale for 3D object on adjustment between real image and 3D object.

4 Implementation and Experiment Result

In this section, we present a result of our experiments and implementation based on WIVA system. The configuration of the proposed system environments is shown in Fig. 6. The building model for validation of our system is also shown in Fig. 6 (A). Size of our building model is as follows: width, height, and wide - 45x62x29cm. We have deployed a topology of five sensor nodes to each story of 3-story building model. Sensor nodes are deployed in close range of communication, so that they can communicate each other by MESH approach. Fig. 6 (B) shows our sensor devices. We designed our own sensor nodes (SSN-P2) with TI's CC2431 chip that includes MCU and radio. SSN-P2 consists of 8051microcontroller, maximum 128KB flash memory and 4KB RAM. Our node size is 56x36mm. The CC2431 chip includes a temperature sensor. Fig. 6 (C) shows Dongle and mobile phone (Samsung SPH-M4500) equipped with Dongle. Dongle for receiving data is designed as SOC chip using Radio Pulse's 8bit 8051 MCU based MANGO.

User can go into 3D modeling viewer by 3D mode or Augmented Reality viewer by AR mode based on the input. To validate efficiency of 3D mode, we have experimented WIVA system for observation of whole building information using 3D mode, as well as fire detection by sensor devices. Fig. 7 shows 3D mode application interfaces on mobile devices. The left side of Fig. 7 describes monitoring of whole structure for a target building, and the right side shows 3D images formalization and sounds alerts functions for detection of fire by sensor devices.

Fig 8 shows the WIVA AR mode experiment. Fig. 8 (Left) shows the mobile device point to marker on target building which is 3m away. When mobile devices point

Fig. 7. 3D Application Interface

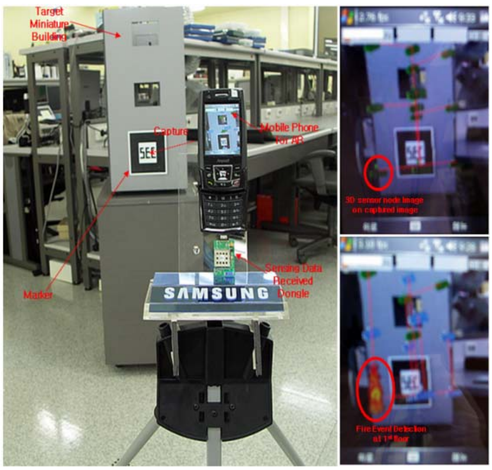

Fig. 8. Experimental Environment for AR and Application Execution Interface

to sensor nodes which are located in dead angle areas, we can observe sensor nodes of as shown in the right figure. In case of AR mode, it has to go through pre-processing such as execution of camera, marker detection, and matrix calculation. To receive data from sensor nodes in WSNs, AR mode goes into Listen status. By default it remains in this status. When a packet is received, event visualization is processed by 3D visualization for each application sensor types on screen. As described Fig. 8, if the sensor type is fire sensor, we applied 3D image effect which is designed in fire shape.

5 Conclusion and Future Works

Nowadays, IT is applied to various industrial fields such as construction site, medical center, military facilities, and so on. In this paper, we proposed WIVA framework with 3D visualization and Augmented Reality technologies in IEEE 802.15.4-based wireless sensor networks. Existing 2D visualization and monitoring system couldn't provide different kinds of user-requested information in dead angle areas such as back of walls or partitions. Moreover, it had a limitation of describing real world situations.

In order to solve these vulnerabilities, this paper presented WIVA framework with 3D visualization and AR technologies. A fire-alert application scenario is deployed in WSN site applying WIVA. The deployment had 3-stroy building miniature and sensor devices with a fire-sensor. Through the WIVA test-bed, we can see that the proposed approach shows high reliability and safety in construction site. Therefore, the proposed WIVA framework can be applied to a variety of construction sites using SHM. Future work is to make an advanced and intelligent visualization system including smart AR for increasing the effectiveness of SHM technologies.

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Environment Objects: A Novel Approach for Modeling Privacy in Pervasive Computing

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Abstract. Maintaining user privacy is a well-known challenge and obstacle to the acceptance of pervasive computing. Privacy has been researched from various perspectives by social science, legislative, and technological communities resulting in an *information-centric* approach that regulates of the collection and use of personal information. However, through the actuation of devices and objects in the user's physical environment, pervasive computing also introduces other significant challenges to a user's physical privacy. Our research introduces an *environment-centric* approach to modeling user privacy and regulating intrusions to physical privacy. We introduce four principles to guide the construction of physical privacy policies and demonstrate how existing information privacy models can be extended to address these aspects of physical privacy.

Keywords: privacy, information privacy, physical privacy, privacy model, pervasive computing, P3P, E-P3P.

1 Introduction

Pervasive computing seamlessly integrates devices, services, and applications into everyday spaces to provide greater autonomy and increased quality of life for users. Sensors supply systems with information about physical spaces and objects, and actuators enable the system to control physical objects and devices in its environment. Service-oriented architectures and web technologies allow pervasive spaces to be interconnected in a modular and interoperable way, enabling much richer functionalities to be created from a world-wide repository of services and applications. However, despite the great possibilities for individual and societal benefit that pervasive computing provides, the management and preservation of user privacy is a well-known challenge and obstacle to its widespread acceptance [6]. Existing solutions [7][11][12] typically approach the privacy problem solely from an information-centric perspective, focusing on the collection and use of personal information in e-Commerce systems. Such approaches have been fueled by social science research [2] and regulatory bodies [3][4][5] to create privacy policy frameworks that allow individuals to exercise control of how their personal information (i.e. social security number or credit card number) is collected and used by e-service providers.

Typically, these information privacy frameworks are based on the Fair Information Practices (FIP), which specify the principles governing the collection and processing

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of personal information [3][4][5]. Essentially, the FIP require four things about a privacy framework: that data practices of a service provider be made openly known to data owners and limited to data necessary for the service, that data owner's give explicit consent to the collection of their information, that sufficient enforcement mechanisms and safeguards are used to protect personal data from misuse, and that service providers audit and redress mechanisms for concerned data owners [1]. Table 1 shows a comparison of the FIP of three major regulatory bodies, the Organization for Economic Cooperation and Development (OECD) [3], the United States Federal Trade Commission (FTC) [4], and the Canadian Standards Association (CSA) [5].

Table 1. Comparison of Fair Information Practices [1]

	OECD	U.S. FTC	CSA
Openness and Restriction of Data Practices	Openness Purpose Specification Collection Limitation	Notice/Awareness	Openness Identifying Purposes Limiting Collection
User Consent	N/A	Choice/Consent	Consent
Enforcement of User Preferences	Use Limitation Data Quality Security Safeguards	Enforcement/Redress Integrity/Security	Limiting Use, Disclosure, and Retention Safeguards Accuracy
Auditing/ Redress of Grievances	Individual Participation Accountability	Access/Participation Redress	Individual Access Accountability Challenging Compliance

Though sufficient for e-Commerce applications, the FIP and derived privacy models are not **a**dequate for preserving privacy in pervasive spaces. Such information-centric approaches neglect any physical intrusions to privacy caused by the actuation of devices and objects in a user's environment, such as a loss of control over personal devices. They also neglect information-related intrusions caused by the actuation of devices and objects, such as increasing the sensitivity of personal information collected by the environment. There are many important reasons for controlling a user's environment, such as maintaining safety and security in the home (i.e. automatically locking doors or turning off unattended appliances), minimizing utilities costs by controlling the operation of appliances, or compensating for a lack of mobility or dexterity; but the technology used should not infringe on an individual's rights to be "left alone" or choose how personal devices are used by others. Our work establishes a new paradigm for privacy modeling in pervasive spaces that includes physical objects in the user's environment and preferences for the physical privacy thereof. The rest of the paper is organized as follows: section 2 provides background and related work on information privacy models, section 3 shows how these existing models can be modified to include physical privacy considerations, section 4 illustrates our new paradigm with an example scenario, and section 5 offers some concluding discussion and remarks on future work.

2 Background and Related Work

The FIP have exerted a large influence on the way privacy models and architectures have been developed. For example, W3C's Platform for Privacy Preferences (P3P) [7] and IBM's Enterprise Platform for Privacy Preferences (E-P3P) [11][12] provide privacy models for e-Commerce systems that are closely akin to the U.S. FTC's guidelines [4]. P3P is a privacy policy framework for the collection of personal information, and E-P3P is a privacy policy framework for the enforcement of a company's published privacy policies. In P3P, an enterprise embeds a privacy policy containing the types, intended uses, and intended recipients of personal data into its web page. A related privacy preference language is used to configure the user's web-browser with the user's privacy preferences [13], allowing the browser to examine the enterprise's data practices for conformance with the user's privacy preferences to determine if personal information should be submitted to the server. The E-P3P provides a high-level policy language [11] and enforcement architecture to regulate the use of personal information after it is collected from the user. E-P3P policies are described in more detail in section 3.2.

P3P in particular has been applied to pervasive computing environments in attempt to regulate the collection of personal information by pervasive devices and services [8][9][10]. In such environments, devices and services announce their data practices [8], possibly extended with special constructs for context awareness [9][10], so that a user's personal privacy agent can collect the policies and determine if the devices/services should be used. Frameworks such as [8] and [12] are adequate to address the collection of personal information in pervasive spaces (from sensors, for example), but are limited to the informational aspects of user privacy. They cannot address the physical privacy concerns caused by the control of devices and objects in a user's physical environment.

3 A New Paradigm for Modeling Privacy in Pervasive Environments

In this section we more formally introduce our new paradigm for modeling privacy in pervasive spaces. First, we present four principles that motivate physical privacy concerns and then show how P3P and E-P3P privacy models can be adapted to model physical objects in a user's environment. Unlike previous work, our privacy model allows preferences to be specified over how these environment objects should be controlled.

3.1 Principles of Physical Privacy

The actuation of devices and objects in a user's environment can intrude upon physical privacy in various ways, such as creating unwanted disturbances, thwarting ownership of personal devices, or negatively affecting the sensitivity of personal information. We have identified four major areas in which physical privacy can be compromised and introduce four corresponding principles to drive the understanding of physical privacy.

- **Silence.** In some cases, individuals may want to separate themselves from unwanted noise in order to rest or relax. "Peace and quiet" is a commonly desired condition that can be violated sound-producing devices like speakers, radios, televisions, and phones. These types of devices may need to be temporarily disabled or muted to prevent unwanted audio stimulus in the user's environment.

- **Personal Space.** In other cases, individuals may desire separation from the presence and activity of others, wishing to withdraw not only from noise but also the proximity and actions of others. A desired "amount" of space can be violated if others enter a user's environment. Preserving this goal by closing "barrier" objects such as doors, shades, or blinds can provide the conditions for this sort of spatial solitude.
- **Sovereignty.** It is common to think of the devices and objects that an individual owns as his or her property, and it is a rarely questioned right of an individual to use their property as they see fit and have the ability and authority to determine how others use his or her things as well. This principle is especially important to maintaining a sense of independence and autonomy in such a networked and interoperable world that allows others in remote locations to actuate local devices.
- **Data Sensitivity.** The last principle is based on the fact that actuated devices and objects can influence the levels of detail of personal information that can be collected by a user's environment. Often, increasing the level of detail of personal information makes the data more privacy *sensitive*. For example, video images at night will likely not reveal much detail, unless a light is turned on, or turning off background noise (i.e. a television or radio) makes audio information more decipherable. Enforcing this principle requires knowing the impact of physical devices and objects upon the environment's information gathering capabilities.

3.2 Information Privacy Policies in E-P3P

In order to understand how the above physical privacy principles can be encoded into privacy preferences, we first review the E-P3P privacy model in more detail to show how it can be adapted to address physical privacy. An E-P3P information privacy policy is written over a set of *terms* that are defined to exist within the enterprise's domain. The simplest set of terms used is a four-tuple (U, P, T, A), where U is the set of data users (i.e. employee roles), P is a set of possible uses for the data (i.e. purposes), T is a set of data types used in the company, and A is their related access modes (i.e. read, write, etc.). Data users, data types, and purposes are arranged into hierarchies allowing policy rules to be specified at different levels of abstraction. A collection of authorization rules written over these terms to either allow or deny employee actions on data types for given purposes, making an E-P3P policy essentially a role-based access control model enhanced with purpose binding. Additionally, a rule may be given a condition C that defines the set of system states in which the given rule should apply. Conditional rules are necessary to encode context-dependent information privacy preferences, such as location-based or activity-based restrictions on data collection. Lastly, a well-defined semantics for evaluating requested operations with the company's internal privacy policies is also provided in [12] which includes a hierarchical unfolding of rules, a default ruling to be used if no other rule applies, and a request evaluation algorithm.

3.3 Environment Objects and Environment Object Privacy Policies

To incorporate the aforementioned principles of physical privacy into a cohesive privacy model, we need to introduce some more terms into the E-P3P vocabulary. First, we introduce a set of *environment object types E* that models the types of physical devices/objects controllable by the system. Any objects that can be physically actuated or operated by a computer, such as various electronic appliances, motorized doors and windows, or made to emit a physical stimulus, such as speakers or electronic displays, need to be included in this set. As in E-P3P, the set of environment object types is arranged into a hierarchy to allow multiple levels of abstraction. We also introduce the corresponding set of actions (i.e. directives) that can be taken on each environment object type *D*. Unlike data types which are accessed in similar ways (i.e. read, write, etc.), each environment object type may have its own set of actions, making *D* a set of sets indexed by the environment object type as opposed to the flat set of information resources actions *A*.

Using the terms (*U*, *P*, *E*, *D*), physical privacy preferences can be written governing the manner in which environment objects are used by other users. Each preference will be a (conditional) rule that determines which users are allowed or denied to act on an environment object for which purposes. Of course, the purpose hierarchy will need to be updated to reflect any new additions of purpose caused by the introduction of environment objects. An *environment object privacy policy* is therefore just a set of these privacy rules over environment objects.

It is worth noting that at this level of detail, we require individuals or their policy authors to know the conditions under which silence, space, and sovereignty, and data sensitivity should be preserved. This requires implicit knowledge of how each object type can potentially violate these goals as well as how each object type potentially could potentially affect the sensitivity of the information collected by nearby devices. Future work will address this limitation.

3.4 Enforcement of Information and Environment Object Privacy Policies

We now discuss two considerations related to enforcing privacy policies in our new privacy model. First, whereas E-P3P required each individual enterprise to define its own set of terms, we assume that there is one centralized and standardized hierarchy for each *U*, *P*, *T*, and *E*. This is partly a practical consideration because translating between multiple hierarchies would make a system much less efficient but partly a simplifying assumption because defining each hierarchy separately with its necessary translation procedures, if not impossible, would be an immensely difficult, labor intensive, and error-prone task.

Second, whereas E-P3P was completely platform-independent, our privacy model employs a service-oriented architecture paradigm. Service-oriented architectures, such as OSGi or Web Services, possess some nice benefits for our privacy model. Service registries provide a convenient mechanism to support the openness of data and object practices as all services are required to publically register their method interfaces. Service invocations can also be easily (logically) intercepted to allow evaluation of service practices with respect to a user's privacy preferences.

More formally, for a given environment, we introduce a set of services S that are present in the user's environment, where each individual service s contains a set of methods M_s that receive data inputs, produce data outputs, and can control environment objects. Each method is also annotated with its purpose (i.e. intended use) in the environment, which is grounded in some benefit to the individual, such as health monitoring, task assistance, etc. An example purpose hierarchy is shown later in figure 2.

User privacy preferences are enforced in our framework when one service (the source) invokes the method of another service (the target). At this point, data is released from the source service to the target service and its providers/users via its method input parameters and released from the target service to the source service and its providers/users via method output parameters. Additionally, the target service may also actuate some environment objects potentially creating a physical privacy intrusion. Intuitively, the evaluation engine retrieves any data preferences or object preferences that apply to the invocation. This is accomplished in two parts. For each potential (user, data type, action, purpose) tuple or (user, object type, purpose) tuple involved the invocation, the corresponding user preferences that are "hierarchically-related" to that tuple are selected. That is, each term in the preference rule is an ancestor to each corresponding term in the request tuple. Next, these available rules must be filtered based on the evaluation of their contextual condition. If the condition evaluates to true, then the system is in a state in which the corresponding preference should be enforced. As in E-P3P, if no preference applies, we return a default ruling. Otherwise, if there is some tuple that is denied, then the whole invocation is denied, else it is allowed in a manner similar to the E-P3P semantics.

4 Example Scenario: Activity Monitoring

We now illustrate the usefulness of our novel privacy model with an example scenario. Mr. Smith is an elderly man living in a smart home environment that, among other things, has the ability to control all the electronic appliances in the home and interact with him via a voice interface. Unfortunately, he suffers from low blood pressure, so blood pressure and fall monitoring services were recently installed, requiring blood pressure sensor, video cameras, and force sensors in the floor to be introduced into the home as well. If a fall is detected, an alert is sent to emergency response team as well as to Mr. Smith's children.

Normally, Mr. Smith has three main privacy concerns. From an information standpoint, he is uncomfortable that "someone may watch him while he sleeps", and prefers that others, including his children, cannot access video data at night. From a physical standpoint, he highly values quiet relaxation in the evening hours and the sense of autonomy in controlling his own appliances by himself. However, since he also knows that falling is a risk for someone with his condition, he wants emergency response personnel to be able to interact with the system's voice interface, have access to video and medical data, and be able to actuate his home devices if there is a medical emergency. In Figure 1, preference rules DR1-DR3 allow the emergency personnel access to Mr. Smith's medical, audio, and video data in an emergency situation, and preference rule DR4 allows Mr. Smith's children to be given information regarding an emergency. Preference rules OR1-OR2 allow the medical response team to control Mr. Smith's speakers and lights respectively. Related user, purpose, data type, and environment object type hierarchies are shown in Figure 2.

One night, as Mr. Smith gets up out of bed, his blood pressure drops drastically causing him to pass out. The fall monitoring system detects this fall from the impact and notifies emergency personnel (DR1) as well as Mr. Smith's sons (DR4) that a fall occurred. The dispatched emergency response team, equipped with a special interface to Mr. Smith's home, requests his blood pressure readings (DR2) and determine that Mr. Smith fell from a drop in blood pressure. After several unsuccessful attempts to establish voice communication with Mr. Smith (DR3 and OR1), the responders remotely access Mr. Smith's video cameras (DR4) but are unable to see anything because of the darkness of the images. They remotely turn on the lights in the house (OR1) so they can locate Mr. Smith and visually determine if he has obvious serious injuries from the fall, such as a broken hip or head trauma. After arriving with this information ahead of time, they treat Mr. Smith for a few minor contusions, notify his children that he is all right, and him back to bed.

Data Policy Rules: <ruling, U, A ,T, P C>
DR1: <allow, Medical/EmergencyResponse, Read, Medical, AssessInjury, "System.FALL_DETECTED">
DR2: <allow, Medical/EmergencyResponse, Read, Audio, Contact, "System.FALL_DETECTED">
DR3: <allow, Medical/EmergencyResponse, Read, Video, AssessInjury, "System.FALL_DETECTED">
DR4: <allow, Residential/Family, Emergency/Medical, Notify, "System.FALL_DETECTED">

Object Policy Rules: <ruling, U, D, E, P, C>
OR1: <allow, Medical/Emergency, Actuate, AudioDevices, Contact, "System.FALL_DETECTED">
OR2: <allow, Medical/Emergency, TurnOn, Lighting/Lights, AssessInjury, "System.FALL_DETECTED">

Fig. 1. Mr. Smith's Information and Environment Object Privacy Preferences

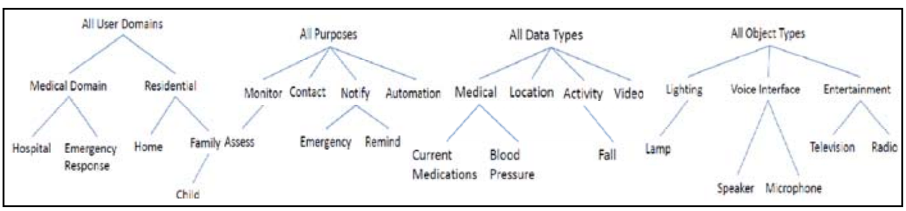

Fig. 2. Sample Hierarchies for Mr. Smith's Activity Monitoring System

5 Conclusions and Future Work

Despite the many potential benefits that pervasive computing could provide in terms of monitoring and task assistance, the many threats that such environments provide to personal privacy often prevents its widespread acceptance. In this work, we demonstrated how existing privacy models, while centered on solely the informational concerns of personal privacy, neglect the physical aspects of privacy, such as the *silence*, *space*, and *sovereignty* of individuals, as well as the impact on *data sensitivity* that the actuation of physical objects in such environments have. Moreover, we demonstrated informally that existing privacy policy models and architectures such as P3P and E-P3P can be modified to account for these privacy concerns by using service-oriented environments and introducing object privacy policies to regulate the above principles in the user's domain. We are currently investigating a formal version of this privacy model, including the relationships between physical privacy intrusions, environment object types, and data types, as well as frameworks and tools to model the system and the user's privacy requirements visually (i.e. with UML) and automatically verify that a user's privacy preferences are satisfied by a system while preserving the availability of critical services.

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Privacy-Aware Web Services in Smart Homes

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Abstract. Smart homes can assist their inhabitants with mental and physical tasks, and monitor their safety and health. However, the systems that empower such homes use sensitive information that could be misused by external systems resulting in violations of the inhabitants' privacy. In this paper, we introduce a Web services-centric solution to handle privacy concerns. Web services provide the functionalities that allow users remotely interact with the systems empowering the smart homes. In addition the solution uses policies to control how Web services handle privacy concerns and penalize those Web services that do not bind to these policies. Moreover the solution uses trust and reputation to select the most trustworthy Web services.

Keywords: Policy, Privacy, Smart Home, Trust, Web service.

1 Introduction

With the latest Information Technology solutions, various types of information are nowadays collected and made available and accessible without a serious control on those who receive and process these information. Information could be the location of a person, the mostly visited Web sites, and the latest credit-card payment. In this paper we focus on persons and the way their personal information need to be treated and shared with respect to some privacy requirements. Smart homes are examples of environments where inhabitants can be constantly tracked, so their privacy quickly becomes a concern. Though this tracking is very useful in some cases (e.g., elderly people), this leads to some inconveniences in people's daily lives. A variety of applications based on wireless sensors detect people's movements and regularly submit this tracking outcome to a central site for processing, post-analysis, etc. A person needs to know the purpose of submitting her personal details to a third party, for how long this party will retain these details, how she could verify that these details were deleted, etc.

Wireless sensors usually constitute the front-end of applications that could be developed using different technologies. In this paper we select Web services though other technologies could be used. Web services provide the necessary functionalities for implementing message communication between distributed entities. Data that wireless sensors submit to applications/Web services could end-up being shared with or passed on to other Web services without the approval of the concerned persons. For example a wireless sensor that tracks the

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available quantity of milk could make a Web service submit a refill request to the nearby grocery. Unfortunately this grocery could submit this request to another one in case it is short of milk without the knowledge/approval of the query's owner. Another example concerns persons who would like to control their home remotely by adjusting the temperature (using their cell phones) 30 minutes prior to their arrival, or checking while on the go if the security alarm is on and be able to change its status. By making all these changes, the system knows that the inhabitants are not at home and hence, their position could be revealed to other entities. In this paper we propose an approach to develop privacy-aware Web services in smart homes. The purpose of this approach is to frame and enforce interactions between Web services based on users' privacy requirements. This enforcement is based on a set of policies and how trustworthy the involved Web services are. The rest of this paper is organized as follows. Section 2 gives some definitions and discusses some related works. Sections 3 till 5 present our approach. Conclusion and future work are briefly given in Section 6.

2 Background

2.1 Some Definitions

Web service. It is *"a software application identified by a URI, whose interfaces and binding are capable of being defined, described, and discovered by XML artifacts, and supports direct interactions with other software applications using XML-based messages via Internet-based applications"* (W3C). A Web service implements a functionality (e.g., BookOrder, WeatherForecast) that users and other peers invoke by submitting appropriate messages to this Web service. The life cycle of a Web service is usually summarized with five stages referred to as description, publication, discovery, invocation, and composition. Briefly, providers describe their Web services and publish these descriptions on registries. Potential consumers (i.e., requesters) screen these registries to discover relevant Web services, so they could invoke them. In case the discovery fails, i.e., requests cannot be satisfied by any single, available Web service, the available Web services may be composed to satisfy consumers' requests.

Privacy. On the Internet, privacy of users can be divided into the following concerns: "*what personal information can be shared with whom, whether messages can be exchanged without anyone else seeing them, and whether and how one can send messages anonymously*"[1]. In terms of standards, the W3C's Platform for Personal Privacy Project (P3P)[2] offers specific recommendations for practices that should let users define and share personal information with Web sites.

[1] http://searchdatamanagement.techtarget.com/sDefinition/0,,sid91_gci212829,00.html
[2] http://www.w3.org/P3P

Trust and reputation. Different definitions of trust and reputation are reported in the literature. On the one hand, reputation is the public's opinion on a subject such as agent, Web service, person, etc. This opinion is objective and represents a collective evaluation. On the other hand, trust is a more personalized and subjective opinion.

Smart home. Several definitions of what smart home is, are reported. A definition states that "*a smart home or building is a home or building, usually a new one, that is equipped with special structured wiring to enable occupants to remotely control or program an array of automated home electronic devices by entering a single command. For example, a homeowner on vacation can use a Touchtone phone to arm a home security system, control temperature gauges, switch appliances on or off, control lighting, program a home theater or entertainment system, and perform many other tasks*"[3]. Another definition suggests "*a dwelling incorporating a communications network that connects the key electrical appliances and services, and allows them to be remotely controlled, monitored or accessed. The three elements in a smart home are: internal network (wire, cable, wireless), intelligent control (gateway to manage the systems), and home automation (products within the homes and links to services and systems outside the home*"[4].

2.2 Some Related Works

Information privacy is an active research field. A legislative body of work known as the Fair Information Practices (FIP) has evolved [5]. The application of the FIP to smart homes can be found in [2]. Several models have been proposed for dealing with privacy issues in smart home environments, most notably [7] in which the concept of "information spaces" is introduced. It is a repository of personal data that can detect privacy violations when an object enters an unauthorized information space. More recently, in [10], a method to dynamically apply privacy measures in the form of data hiding techniques to data captured in a smart home environment is proposed. This is achieved by using the environmental context to determine the appropriate privacy measures.

In [3], Benbernou et al. discuss a privacy-agreement model for Web services. The authors note that despite the increasing number of privacy policies that businesses post, individuals are not yet convinced with how these businesses handle personal data. As a result, these individuals continue to be reluctant to disclose these data. Benbernou et al. note that privacy policies are merely promises that are sometimes not fulfilled. Therefore, a dynamic privacy-agreement model that consists of rights and obligations would be deemed appropriate and would accommodate new business strategies and changes in laws and regulations.

In [4], Chafle et al. discuss the centralized orchestration of Web services composition that is subject to some data flow constraints. In this type of orchestration, all data are routed through a central coordinator that has access to

[3] http://searchcio-midmarket.techtarget.com/sDefinition/0,,sid183_gci540859,00.html

[4] http://www.cat.csip.org.uk/_library/docs/Housing/smarthome.pdf

the input/output data of all the component Web services. Chafle et al. note that (i) in certain business scenarios, Web services may apply restrictions on the source/destination of the data received/sent and (ii) handling these restrictions using current security mechanisms (encryption, authentication) is sometimes inefficient. Chafle et al.'s solution uses three modules (decentralizer, topology filtering, and deployment) and adopts a decentralized orchestration by splitting a composite Web service into a set of partitions, one partition per component Web service. A partition acts like a proxy that processes, transforms, and manages all incoming/outgoing data in compliance with the restrictions that a component Web service poses and the data requirements that a composite Web service sets.

In [12], Xu et al. note that concerns about user privacy need to be handled during the development process of composite Web services. The number of people who routinely access the Web continues to grow, which has exacerbated these concerns. In response to this exacerbation and the various P3P shortcomings, Xu et al. propose a framework to build privacy-conscious composite Web services. Initially when a user provides data to a Web service, the user wants to ensure that these data will be used in a manner that complies with her privacy preferences. If this is the case, the user has the opportunity to request a model of the Web service so that she can know how this Web service processes and shares data. In Xu et al.'s framework, automated techniques check the compliance of a Web service's model with a user's privacy preferences. If the check succeeds, the user forwards the request to the Web service for processing. Otherwise, the user can forward this violation as an obligation to the composite Web service, and mandates that the obligation should be enforced.

3 Our Approach to Handle Privacy in Smart Homes

Smart homes can benefit their inhabitants in different ways. They assist them with mental and physical tasks, monitor their safety and health, and notify others in case of emergencies [1]. In smart homes, however, much sensitive personal information will be used by the systems empowering these homes and such information could be misused by external systems, which could result in violating the inhabitants' privacy. Access to such information needs to be controlled so that smart homes protect sensitive information and thus, turn out reliable and trustworthy.

Fig. 1 illustrates our proposed approach to make smart homes take into account users' (or inhabitants) privacy concerns. Two levels are shown in this figure: physical and logical. The physical level represents a smart home with all its constituents such as microwave, TV sets, and lights. Each constituent binds to a group of wireless sensors for monitoring and data collection purposes. For example, decisions on temperature adjustment in a room are made based on the data that sensors collect and submit to the logical level. The way wireless sensors are set up and function is outside this paper's scope. In addition we assume that collected data are noise-free.

The logical level represents the software applications that control the smart home's constituents and take appropriate actions, as need be. This control is driven by scenarios such as temperature adjustment, light switching, etc. As mentioned in Section 1, software applications are built-upon Web services that are sometimes put together to constitute composite Web services [6]. An example of composite Web service could be food order where at least three component Web services are used: OrderPlanningWS (to assess the current level of available food prior to initiating any new order), OrderFulfilmentWS (to submit the order to an agreed-upon grocery), and OrderDeliveryWS (to arrange for delivery as per the user's preferred times). Exchanging information between these Web services needs to comply with users' privacy concerns as it will be shown in Section 4. Moreover to ensure that the selected Web services preserve the privacy of the smart home's inhabitants, it is critical to rely on a pool of trustworthy Web services, which is going to be discussed in Section 5. To keep the paper self-contained, Web services definition (WSDL), advertisement (UDDI), invocation (SOAP), and composition (using BPEL) are outside this paper's scope.

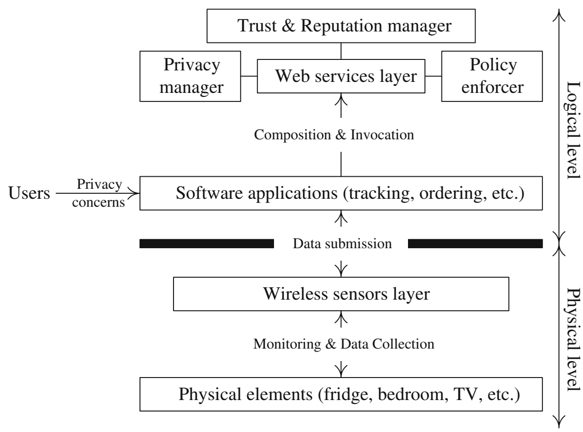

Fig. 1. Representation of privacy-aware Web services in smart homes

In the logical level three modules are connected to the Web services layer. The privacy-manager module makes sure that the privacy concerns of a person are communicated to the Web services that satisfy her needs. These concerns are collected through appropriate interfaces and could be about the maximum number the user's credit card is retried in case payment fails. The policy-enforcer module comes into play at run-time. It initiates the policies that go along with the privacy manager's requirements and checks if these requirements are met. Details on both modules are given in Section 4. Finally, the trust-and-reputation-manager module ensures that only trustworthy Web services are selected to satisfy users' needs.

4 Types of Privacy Concerns

In Fig. 1, users interact with software applications through dedicated interfaces so they can specify their privacy concerns. These concerns will be reflected at the Web services level thanks to the privacy manager. For example a user does not let its Web services receive data from un-trusted sources such as other Web services and Web sites. In the following we suggest some types of privacy concerns:

– Data source: a user could identify a list of Web services from which its Web services would accept data without checking their "credentials" [8].
– Data destination: a user could identify a list of Web services to which its Web services would pass on data without checking their "credentials" [8].
– Data retention period: a user could set the acceptable time for Web services to retain her data whether these data were subject to changes or not. When this time elapses, the data should be either deleted or forwarded.

Basically the Web services that satisfy a user's request trigger policies [9] to make sure that this user's privacy concerns are properly handled. In our approach we define policies as if-then rules (e.g., **if** appliance tries to connect to home PC **then** disallow) and identify two types: simple and composite. The composite policies as their name hints use other policies whether simple or composite. In addition to both types of policies, each policy is weighted, which permits to resolve cases of conflicting policies (e.g., an appliance may need to connect to the home PC to send an email confirmation).

Making sure that a user's privacy concerns were "seriously" taken into account at run-time requires two steps: monitoring and post-analysis. The policy enforcer is in charge of performing both steps. The monitoring step runs in conjunction with the execution of a composite Web service and consists of tracking data movement (in and out data) and interactions between Web services. The outcome of this tracking exercise is reported in log files (structure not detailed here). The post-analysis step uses the log files and re-constitute how data were exchanged and what policies were triggered.

In addition to privacy concerns, smart home technologies could introduce new security holes not encountered before that may lead to additional privacy concerns. Imagine the networked refrigerator being used by a grocery store to connect to the home PC to retrieve some credit card information or even browsing history.

5 Selecting Trustworthy Web Services

Autonomy of Web services' providers and the lack of details on Web services' behaviors prior to execution undermine the assumption that Web services will preserve users' privacy as expected. Unfortunately, policies turn out useless when providers purposely lie about the real usage of user data by simply switching to a different piece of software that violates these policies. To address this specific shortcoming in our approach, we select Web services using two criteria:

trust and reputation. A Web service is trustworthy if it meets a certain announced trust level that tells how much the Web service is willing to preserve a user's privacy. We assume that a Web service is willing to preserve privacy if its provider is willing to do so. Preserving a user's privacy does not depend much on how a Web service performs (i.e., non-functional features) but rather on the reputation of its provider. We define trust as "*a measurable level of subjective probability with which a user* $\mathcal{U}$ *assesses that a Web service provider* $\mathcal{P}$ *will preserve* $\mathcal{U}$*'s privacy policies, before* $\mathcal{U}$ *can monitor such action*" and reputation as "*an expectation that* $\mathcal{P}$ *preserves privacy based on other users' observations or information about* $\mathcal{P}$*'s past behaviors*". Reputation is usually associated with a central authority that accepts to manage members' reputations. Contrarily, trust requires that members should cooperate and share information to manage their own trust relationships. According to a recent review on Web services reputation and trust [11], reputation is more considered than trust. We aim at combining both by adding two extra components to our proposed approach:

- A central authority (not represented in Fig. 1) to be in charge of the reputation of Web services. It maintains scores of how much providers of Web services preserve privacy so far.
- A Trust and Reputation Manager (Fig. 1) which mainly maintains, on behalf of its user $\mathcal{U}$ (smart home), a set of (un)trustworthy Web services providers. Positive/Negative scores of the (un)trustworthiness per provider are given by $\mathcal{U}$ based on previous experiences. This set called Trustworthy Service Providers ($\mathcal{TSP}$) contains (un)trustworthy providers with whom a smart home has had good/bad experiences (without privacy problem/privacy policies violated).

In our approach the selection priority is given to $\mathcal{TSP}$ over the central authority since our aim is to promote personalization in smart homes. We also assume that a Web service is trustworthy if its provider is trustworthy. Therefore a Web service is selected as follows:

- If a Web service has a provider that is trustworthy according to $\mathcal{TSP}$ and fulfills the user's requirements, then it will be selected. The trustworthiness of the selected Web service is maintained using the monitoring and post-analysis steps (Section 4). For example, the grocery Web service $g\mathcal{WS}$ with whom $\mathcal{U}$ had a good experience would likely to be selected next time for other milk order.
- If such a Web service does not exist in $\mathcal{TSP}$ the central authority is consulted by the Trust and Reputation Manager and a trustworthy Web service (from a trustworthy service provider) is selected (assuming this provider is not in the list of untrustworthy elements of $\mathcal{TSP}$). For instance, if for any reason $g\mathcal{WS}$ is no longer available, the Trust and Reputation Manager of $\mathcal{U}$ has to consult a central authority to look for another grocery Web service with good reputation.

6 Conclusion and Future Work

Applications that empower smart homes need to use much sensitive personal information to accomplish their tasks in a proper way. Such information, however, could be misused by external systems, which violates inhabitants' privacy. To address this issue, we have introduced a Web services-centric solution that provides a dynamic model for managing privacy issues. It is dynamic as it would allow new household items to be configured and inherit the pre-existing privacy policy. For future work, we plan to refine our trust and reputation model, and then implement a prototype of the proposed solution.

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Concept and Design of a Video Monitoring System for Activity Recognition and Fall Detection

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Abstract. A video monitoring system is presented which aims to detect falls and other critical situations of people living single. Seniors are particularly likely to experience high-risk situations. If, for example, an elderly person falls and cannot call for help independently, it often takes hours or even days until the emergency is noticed and assistance will be provided. The presented video monitoring system is to mitigate situations of this kind. If an emergency is detected, an automatic alarm will be raised. One of the main aspects of the developed assistance system is to be as unobtrusive as possible to achieve a high acceptance among the users. Moreover, the system needs to work very robustly in individual home environments. The fall detection system is part of an extensive real-life Ambient Assisted Living (AAL) concept with many other extended support functions.

Keywords: Computer Vision, Tracking, Fall Detection, Assisted Living, Assistive Technology, Elder Care, Senior Housing, Housing for the Elderly.

1 Introduction

The consequences of a fall are often more severe among the elderly than among younger people [1, 2]. The situation is especially critical with elders living single. If they cannot independently call for help after a fall it often takes hours or even days until the emergency is detected by relatives, neighbors, or medical personnel. During this period of time the condition of the person continuously deteriorates [3]. The longer this period of time is, the higher the rate of morbidity-mortality is [3, 4].

Worldwide, numerous research groups are working on the development of reliable fall detection systems. Currently, there are two main approaches. First, accelerometers can be employed to detect falls [5, 6]. One of the main drawbacks of this approach is that the person has to wear the accelerometer and many elder people forget to put on or refuse such devices. For that reason, the second approach aims to detect falls with video cameras [7-9]. In most cases, however, more than one video camera has to be placed in a room, possibly leading to limited acceptance.

Considering the above aspects, the authors only use a single camera per room in order to achieve high acceptance of the monitoring system by the user. Nevertheless, the system is designed to work very robustly in individual home environments. The

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presented video monitoring system is to mitigate the risk described above for elder persons living single. The automatic fall detection is designed to minimize the severity of such instances.

The monitoring system will be embedded into an existing AAL project. The AAL project was launched by the University of Kaiserslautern in cooperation with a local housing society in 2003, aiming to enable elder persons to live independently as long as possible in their accustomed homes [10-12]. Three major areas of interest were identified: health, safety, and comfort. While health and safety are important issues to ensure an independent life, comfort aspects are also considered to achieve satisfactory acceptance among the users.

2 Technical Concept

In the current approach a video camera "Q22M Secure" by MOBOTIX (Kaiserslautern, Germany) is used. This camera features a fish-eye lens (image angle: horizontally 180 degrees, vertically 160 degrees). The fish-eye lens enables the fall detection system to monitor a complete room with a single camera. Additional features of the Q22M include an integrated HTTP server for downloading images, Power over Ethernet (PoE, IEEE 802.3af), and an unobtrusive design.

The camera positioning is crucial for video monitoring systems. In [7] and [9], the cameras are mounted on the walls. The advantage of this approach is that a person is seen sideways and mostly has a clearly defined outline. The disadvantage, however, is that considerable occlusions can occur which can lead to tracking problems. Thus, more than one camera is needed to avoid such problems.

In order to reduce the number and size of occlusions, in the presented approach the camera is mounted at the ceiling as in [8]. This position allows an excellent overview (Fig. 1) and nearly no occlusions occur. Usually only one camera is required per room. The disadvantage is that a person is mostly observed from above so that postures cannot be easily distinguished. Thus, the authors only consider the activity of a person to detect emergencies, such as falls.

It is assumed that a person's activity level depends on his or her actual position in a room. Hence, a room is divided into different areas which can be assigned different activity zones. Three different activity zones are implemented:

- Zone 1: Standard zone, comprising all areas unless listed below
- Zone 2: Areas with low activity (bed, sofa, areas with chairs or armchairs)
- Zone 3: Entry or exit areas (e.g., doors).

There is reason to assume that the activity level in zone 2 is usually lower than in zone 1 because zone 2 comprises the areas where a person takes a rest (for example reading a book, watching TV, or sleeping). Since only activity is considered for fall detection, the sensitivity of the monitoring system for detecting low activity is lower in zone 2 than in zone 1. I.e., inactivity may last longer in zone 2 than in zone 1. Zone 3 has a special purpose because a person can only enter or leave a room through this zone. Thus, the movement of a person will always start in zone 3 when the person enters the room and it will always stop there when he or she leaves the room. Thus, zone 3 is crucial for deciding whether or not there is a person in the room. An example of such a zone definition is shown in Fig. 1.

Persons need to be tracked in real-time in order to obtain continuous information about their location and activity. This is no trivial task since the home environment is very individual and the appearance of a person can change. Changing lighting conditions and shadows also contribute to this challenge.

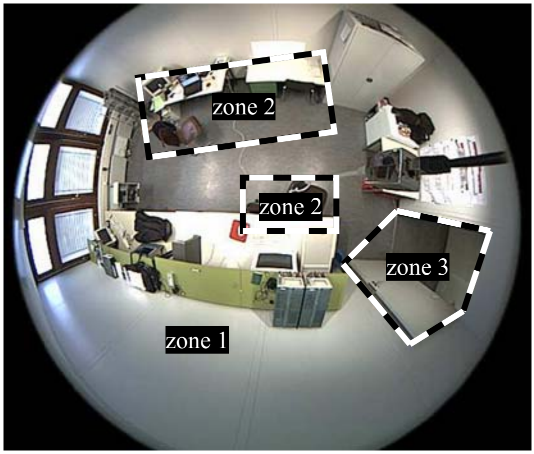

Fig. 1. Bird's eye view of the test room. Different zones are marked: Z1: standard zone. Z2: resting zone. Z3: entry and exit zone.

3 Realization

The video monitoring software was written in C#. The image processing section uses OpenCV, a powerful, open-source computer vision library [13]. The code for the actual fall detection consists of three parts: image download and pre-processing, motion analysis, and fall detection. Each new camera image is first pre-processed. Subsequently, motion analysis is carried out. Finally, the emergency detection algorithm evaluates the result thereof.

3.1 Motion Analysis

Three color images are needed for motion analysis: the current frame I_t, the previous frame I_{t-1}, and an background image B_t. Since changes can occur in the background (e.g., by changing lighting), the background image is adapted: B_{t+1} is computed using alpha blending [14] of B_t and I_t. The first background image B_0 is an image of the empty room. This method is known as exponential moving average. In order to prevent the adaptation of the person (foreground object) into the background image, only parts of B_t are adapted (see below).

From the images I_t, I_{t-1}, and B_t, two binary (black-and-white) images are generated: a background subtraction image (BSI) and a frame difference image (FDI). First, the absolute difference of I_t and B_t for the BSI and of I_t and I_{t-1} for the FDI is calculated. Subsequently, the resulting color images are converted to grayscale. Finally, the resulting grayscale images are converted to binary applying a threshold filter.

If B_t matches the real background, all white areas in the BSI can be assigned to foreground – the person. In reality, however, this is typically not the case so that some white areas in the BSI are not caused by the person but by differences in color or hue between B_t and the real background. In the FDI all white areas are caused by current changes in the room. Combining BSI and FDI yields a new binary image – the segmentation image (SI). In the SI only those distinct white areas of the BSI are taken into consideration in which changes occurred at least in parts of the respective area. In the following those white areas will be referred to as SI areas. Since changes in the background occur only temporarily, most color differences between B_t and the real background do not cause SI areas. The disadvantage of this approach is that a person cannot create an SI area if he or she does not move. Nevertheless, the SI proved to be a good tool for motion analysis.

The motion analysis can be described by the Moore automaton shown in Fig. 2. Currently, a maximum of one person per room is allowed. The program starts in S1 (no person in the room). In that state the system waits for a person to enter through zone 3 (entry or exit areas). If there are one or more SI areas in zone 3 larger than p pixels, it will be assumed that a person enters the room and the largest of these areas will be assigned to the person. This very abstract approach had to be chosen because sometimes a person causes more than one SI area. This happens if the contrast between person and background is too low in some areas. Beside SI areas caused by the person there are often others caused by shadows. The largest SI area can nearly always be attributed to the person, but it is very difficult to decide which of the smaller ones are caused by the person as well. The limit p was introduced to avoid false detections caused by disturbances (e.g., due to changing lighting) in case no person is entering. If a person is detected (C1), the program will change to S2.

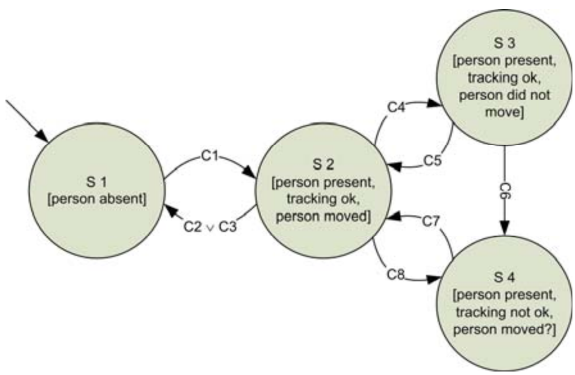

Fig. 2. State diagram of the Moore automaton for motion analysis

In S2 the FDI is used to establish whether a person's position or posture changed. If not, the zone the person is currently situated in will be identified. If this is zone 3 (entry or exit areas) (C2), it will be assumed that the person has left the room and the program will change to S1. If any other zone is identified (C4), S3 will be entered. If changes do have occurred, the person must have moved and the system will evaluate the largest SI area which is larger than p pixels. Three cases need to be distinguished:

– If only one SI area larger than *p* pixels is found, this area will be assigned to the person and the program will remain in S2.
– If two or more SI areas are found, it will be determined whether the largest SI area is in zone 3 (entry or exit areas) and is approximately as large as the area A_d of a door (A_d has to be defined in advance for each room). If so, the second-largest SI area will be assigned to the person. Otherwise, the largest SI area will be assigned to the person. This distinction has to be made to ensure that a person is correctly tracked after entering a room and closing the door. The program remains in S2.
– If no SI areas are found, the last position of the person will be determined. If the last position had been in zone 3 (entry or exit areas) (C3), it will be assumed that the person has left the room and the program will change to S1. If the last position had been in any other zone (C8), it will be assumed that the person still is in the room but the current position of the person will be unknown. In this unlikely case, the program will change to S4. This behavior can only emerge if either occlusions occur or if a person causes many, very small SI areas due to insufficient contrast between person and background. In S4 the analysis is repeated with each new SI until one or two large enough SI areas are found so that the new position of the person can be determined (C7) and the program will change to S2. Since the current position of the person is unknown in S4, it cannot be determined whether or not the person has moved. In order to avoid problems with the fall detection, in S4 it is assumed that the person always moves. Usually the program remains in S4 only for a few seconds. Hence, this assumption should not cause any problems.

In S3 the FDI is used to establish whether or not the person's position or posture has changed. If not, the program will remain in S3. Otherwise the system will look for the two largest SI areas like in S2 (same case distinction) and the program will change to S2 or S4, respectively.

After the motion analysis, the background image B_t is adapted. Depending on the current state, some parts of B_t are adapted whereas others are not. In S1 only areas not belonging to zone 3 (entry or exit areas) are adapted. This way, the adaptation of an entering person into the background image is avoided. In S2 and S4 only areas are adapted which are no SI areas. In S3 the person does not move and therefore causes no SI areas. In order to avoid the adaptation of the person into the background image the last SI of S2 (person moved) is used: B_t is only adapted in those areas which had been no SI areas in the last SI of S2.

3.2 Emergency Detection

After the motion analysis the person's activity is analyzed to detect falls and other emergencies leading to strikingly long periods of inactivity (e.g., circulatory collapse). The emergency detection algorithm comprises two steps.

First, the time since the last detected movement of the person is determined. If this time exceeds a certain limit t_L (1), the system assumes an emergency. The value of the time limit depends on which zone the person is currently situated in.

There is no time limit defined for zone 3 (entry or exit areas) because if the movement of the person stops in zone 3, the system will assume that the person has left the room (see 3.1). This first part of the emergency detection is designed to detect serious falls leading to a complete cease of any motion. If, for example, the person moved only a little bit after the fall, this approach for fall detection would not work.

$$t_{\mathrm{L}} = \begin{cases} t_{\mathrm{L1}} & \text{if person is situated in zone 1 (standard zone)} \\ t_{\mathrm{L2}} & \text{if person is situated in zone 2 (areas with low activity)} \end{cases} . \tag{1}$$

Thus, in order to allow the detection of such falls not leading to complete motionlessness, in step two a statistical analysis of the observed motion is carried out. For each period of motion and no motion, respectively, the length of the period is determined. For periods with motionlessness the zone in which the person is currently situated in is also taken into account. The sums of these different periods are computed in one-minute-intervals so that the following statistics can be established:

t_1: time per minute with person at rest in zone 1 (standard zone)
t_2: time per minute with person at rest in zone 2 (areas with low activity)
t_{m}: time per minute with person moving

As in step one of the emergency detection, stopping in zone 3 is not evaluated because the cease of movement in this zone will be interpreted as a person having left the room (see 3.1) and the statistical analysis will be stopped. Statistical analysis starts again when the person reenters the room.

Under normal circumstances there are two different cases. In the first case the monitored person is active and t_{m} is assumed to be substantially greater than t_1 or t_2. In the second case the person takes a rest (for example watching TV or sleeping) which results in larger values for t_2 and lower values for t_{m}. In case of a fall, t_{m} will decrease as well. Depending on which zone a fall occurred in, the fall leads to larger values for t_1 and t_2, respectively. Thus, light falls (i.e., not leading to complete cease of motion) in zone 2 and regular rest cannot be distinguished. Hence, performing the statistical analysis, light falls can only be detected if they occur in zone 1.

It is assumed that in case of a light fall in zone 1 the person usually remains in that zone and the percentage of inactivity repeatedly exceeds a certain level α. Hence, a fall will be assumed if the following inequation (2) is satisfied for each minute within a time interval of k minutes:

$$\frac{t_1}{t_1 + t_2 + t_m} > \alpha \tag{2}$$

Since the inequation has to be valid for each of the k minutes normal activities with several short periods of inactivity in zone 1 do not trigger false alarms.

4 Experimental Results

The presented video monitoring system was tested in a living lab. There are a few windows on one side of the room and a door on the other (see Fig. 3). Besides some laboratory equipment there are a few tables and chairs in the room. After the definition of the zones, some preliminary tests were carried out. The system was tested with typical activities (e.g., working at a desk or watching TV) and several simulated falls. Serious falls with no movement after the fall were evaluated as well as falls with movement afterwards. The effect of a switched-on TV was tested to determine whether the picture on the screen will result in erroneously detected motion. Tests were carried out under different lighting conditions (artificial lighting from the ceiling or only daylight from the windows).

With artificial lighting from the ceiling and only little light from the windows excellent results were achieved. The person could easily be tracked, regardless of the location and the kind of movement (see left picture of Fig. 3). Falls were correctly detected and rate of false alarms was close to zero. The TV had no effect on tracking the person or the fall detection.

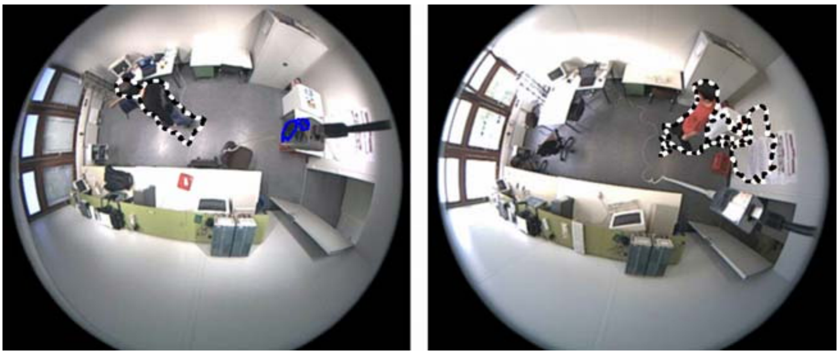

Fig. 3. Results of tracking with artificial lighting from ceiling (left) or with daylight only (right)

In bright daylight, distinctive shadows appeared (see right picture of Fig. 3) so that sometimes the person could not be tracked correctly. These tracking errors often led to undetected falls or false alarms. Rapidly changing lighting conditions (e.g., due to clouds passing by) further exacerbate the situation. For that reason in the future the system will be enhanced with a shadow compensation algorithm to reduce the impact of the lighting conditions on tracking a person.

5 Conclusion

In this paper a video monitoring system is presented capable of detecting falls of elder persons living single. Beside falls other emergencies leading to strikingly long periods of inactivity can be identified (e.g., a circulatory collapse). The system only requires a single, unobtrusive video camera mounted at the ceiling per room. Thus, a very unobtrusive system was achieved. An intelligent tracking algorithm was developed based on movement recognition. Falls and other emergencies are detected by assessing a person's activity level in combination with his or her position in the room. For this purpose an approach with different activity zones was introduced.

Under artificial lighting from the ceiling excellent results were achieved. However, if the main light entered through the windows, sometimes distinctive shadows led to tracking errors and thus to undetected falls or false alarms. In order to mitigate this shortcoming, the system will be enhanced with a shadow compensation algorithm in future works.

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Design and Trial Deployment of a Practical Sleep Activity Pattern Monitoring System

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Abstract. Sleep disorders are common in the elderly, can be distressing to both the elderly and their carers, and often contribute to institutionalisation when the disruptive night behaviour of the older person exerts its toll on the carer. The main way of determining Sleep Activity Pattern (SAP) and aberrant changes in the normal sleep/wake cycle is through verbal reports of the patient and his/her carer, information that can be subjective, incomplete and unreliable. An emerging modality for SAP monitoring is actigraphy, involving the use of wearable sensors commonly based on accelerometers. To bring actigraphy to the next level in order to reap its benefit for the elderly population at large, one must consider its deployment in realistic settings such as nursing homes and in the homes of the subjects. In this paper we provide a brief account of the trial deployment of our SAP monitoring system in a nursing home, where data was collected from fifteen elderly residents for a period of two weeks each. Besides providing an objective basis for obtaining sleep related information from patients who are often unable to remember clearly how well they have slept, our system benefits staff and doctors by providing more accurate information as a supplement to the sleep diary, and hopefully even eliminate the need for the latter. Preliminary results are reported herein.

Keywords: Sleep Activity Pattern Monitoring, Circadian Patterns, Wireless Sensor Networks, Service Oriented Architecture.

1 Introduction

Older persons, especially those with dementia, often have problems with maintaining alertness in the day and sleep in the night. As dementia advances, the normal sleep-wake cycle can be reversed, resulting in daytime sleepiness and restlessness at night. Problems with maintaining a normal sleep-wake cycle can be associated with BPSDs (Behavioural and Psychological Symptoms in Dementia), resulting in much anguish and a poor quality of life to both patients and carers. Work by Craig and co-workers [1], has shown that sleep problems in dementia are common, diverse and highly distressing to patient and carer. However, objective information on Sleep Activity Pattern (SAP) is difficult to obtain. Currently, the main way of determining SAP and

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aberrant changes in the normal sleep-wake cycle is through verbal reports of the patient and his carer. This information can be subjective, incomplete and unreliable.

From a clinical perspective, accurate SAP information is important when one attempts to improve the quality of life of patients and carers by means of strategies to improve sleep. Reliable and objective accounts of SAP will enable accurate assessment of responsiveness to prescribed interventions and therapies.

It is our goal to automatically capture and chart the daily SAP for elders in staying nursing homes or their own homes. In this paper we present the design and deployment of a SAP monitoring system in which we have successfully collected sleep related data for elderly residents of a nursing home. The objectives of the present study are:

i) to validate an actigraphy enabled continuous real-time SAP monitoring system with wearable sensors. Ground verification is provided by sleep diaries.
ii) to process the data obtained and present them real-time, in a summarised and easily understood format for the attending care staff and clinician.

Related work and trial requirements are presented in Section 2. Section 3 discusses the device selection and prototype development phase of the project, during which a number of architectural modifications were made in order to improve the robustness of the system. Section 4 presents design improvements to the first version of the prototype followed by the trial deployment and data collection phase of the project. Trial data collection was undertaken in three stages, each covering a cohort of five residents. Section 5 presents a design of the algorithms for processing of sleep data. Section 6 presents the results. Section 7 presents conclusions, summarizing the contributions of this paper and mentioning future directions.

2 Related Work and Trial Requirements

Though there is a lot of work on sleep monitoring, and even in the area of actigraphy [2], not much is known in terms of attempting to correlate sleep activity patterns with behavioral outcomes (patient) and caregiver stress. Automated intervention, one of the goals in our work, is also relatively new. Paavilainen et al [3] conducted a survey among 16 residents of a long term care facility for elders. They established an association between changes in actual health status and circadian activity rhythm. Thus they concluded that telemetric activity monitoring helps detect long term changes in health status among older adults in their normal environments. Lotjonen et al [4] provided details of the long term on-line monitoring of the activity of elderly, commenting on the ability of the device to discriminate sleep/wake patterns during night time and during napping. While polysomnography is the gold standard, they are able to demonstrate that the results of the long term on-line approach based on wearable sensor is of acceptably high quality.

Automated observation scenarios tends to focus on context awareness and activity monitoring [5-8]. Scanaill et al [9] describe an accelerometer based mobility tele-monitoring device in a smart home environment. The accelerometer is able to classify different activities such as lying, sitting, standing and walking. It collects statistics of each of these activities and periodically sends summaries to a server via SMS messages.

The systems surveyed do not take a service oriented view towards building a monitoring system for wearable devices. Such a view should take into account the need for, among other factors, scalability and extensibility of the system, so that it can be developed into a full-fledged service. One must take into account factors such as security, mobility, availability, scalability, extensibility and ease of incorporating new devices and algorithms. As we addressed the problem, it was clear from the start that a system needed to be put in place in the living quarters of the elderly. The system would have to be wearable, since the elderly would be tracked in their daily activities indoors and perhaps outdoors as well. The system would also need to be easy to use and robust. A wireless device was the obvious solution, and since our project team had previous experience [10], with deploying wireless sensor networks in a nursing home environment, this experience was very useful for building the Sleep Activity Pattern monitoring prototype. Since we had to analyse the patterns of signals being monitored, areas such as artificial intelligence and data mining, as well as pattern classification to accurately characterize sleep / wake activity were important capabilities needed for the success of the work. The team had prior experience in these areas [11-13].

3 Device Selection and Prototype Development

In our search for an appropriate device we found that commercial systems to chart SAP were already in existence. However they were either proprietary or custom designed for a single use case. Such systems also tended to be targeted towards clinical end-users in that the data provided were directed towards physicians. We initially selected one such system and built our first prototype [14] using a proprietary wearable sensor, the Vivago Wristcare™ [17], to help in real-time SAP monitoring.

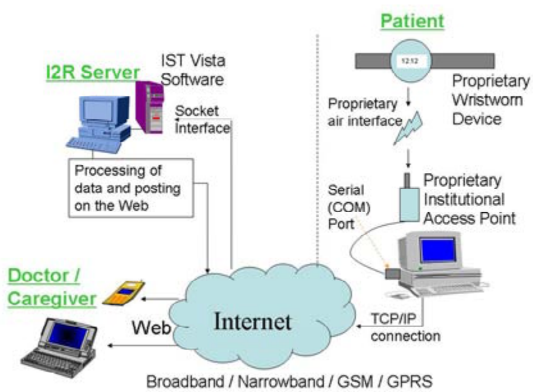

Fig. 1. Sleep activity pattern monitoring prototype version 1

The accelerometer used had a comfortable form factor and shape (its appearance was just as a wristwatch), to be used by the elderly. The system was available in two configurations, one for home use and the other for use in institutions. The home unit did not meet our requirements for continuous monitoring of activity, so we created a remote monitoring system by extending the institutional system to suit our requirements. With this modified system, activity data from patients' homes could, in principle be received at a remote server machine, which was then made available to doctors / nurses / caregivers through a web interface (Fig 1).

4 Design Improvements Trial Deployment and Data Collection

The first prototype relying on the Vivago™ wearable sensor generated quite well designed reports for the doctor. Though this aspect was certainly one to be preserved, there were several drawbacks in this prototype because of which we decided to explore other options. The reasons are:

a) The system was proprietary and had a closed design. It was designed to be used in specific environments and was not possible to customize and use in other scenarios.
b) The institutional system required the use of potentially multiple base stations, each being fairly expensive and thus not affordable in nursing homes for the elderly.
c) The sensor platform and hardware and software interfaces were closed. The raw data was not available to the end user, and thus it was not possible for us to develop new algorithms for the detection of aberrant behaviour of a particular sort, or the incorporation of signal processing software for various purposes.

Because of these reasons we decided to experiment with another wearable accelerometer, manufactured by Alive Tech™ [18].

4.1 Design of the Revised SAP Monitoring System

The revised system is mobile, robust and scalable and adopts an extensible architecture. We envision the next generation of actigraphy to consist of extensible systems based on acquisition sensors with easy to plug and play interfaces, adaptable and customizable GUIs and the ability to incrementally develop a variety of software systems ranging from simple UI software, all the way to complex Artificial Intelligence based systems that accurately track activities in an ambient assistive environment. We envisage that the home of an elderly person will one day be fitted with various kinds of sensors in an extensible manner – within a service-oriented architecture (SOA) as discussed in [15]. Each type of sensor would provide raw data, events or information (processed data) to the system on a continuous basis. Although the architecture is the same as that in Fig 1, internally the modules are differentiated (Fig 2), and it is possible to interface these modules with a variety of hardware and software alternatives. The system retains the benefits of mobility and is able to track the signals in indoor and outdoor environments. It is robust, in that it is able to detect situations such as loss of connectivity to the server and power outage at forwarding node (currently a PDA phone), or loss of connectivity to the client due to battery power outage at the device. Once these situations are detected, they are highlighted and an appropriate alert is sent out for intervention. This way, trial data is kept within limits of acceptable loss.

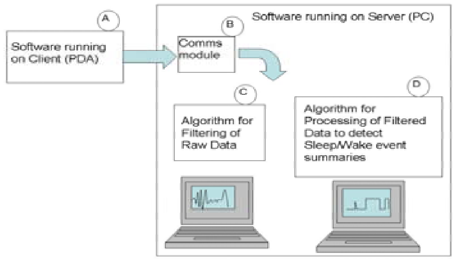

Fig. 2. Filtering & summarizing of data, in V2 of prototype

The system is scalable in that it can be deployed on potentially hundreds of users simultaneously with no significant degradation in performance.

The hardware components of the system are:

> **Sensors:** Bluetooth-enabled wrist-worn 3-axis accelerometer sensors for measuring activity
>
> **Gateway device:** Bluetooth enabled PDA-phone/PC to relay sensor data to a remote site.

The accelerometer sensor connects to the gateway to send data to a remote server. The gateway device connects to the server through internet using wired broadband, Wi-Fi or GPRS/3G connectivity. The interaction between the gateway device and server is implemented using web services. The gateway device currently runs on Windows platform and software applications have been implemented in .NET while the server runs on a Linux platform and uses Java based application server (Axis2 on Tomcat). The processed results can be viewed online on the Internet via a web URL. Though the prototype does not address all the security issues at this time, it is possible to add a variety of security / access-control capabilities as needed.

The main advantages of our system architecture are a) it is open and extensible, thereby allowing incorporation of new sensors and sensing modalities, hardware devices and software modules in an incremental manner; b) it can be personalized and customized to suit the needs of patient, care-giver or doctor and c) it permits the placement of self-help capabilities. Although we have not yet experimented with self-help, we feel that features based on self-help should be built into such applications to allow family members of the persons themselves to monitor their near one's well-being.

Furthermore, the system is extensible and flexible. If newer sensing devices should appear it is straightforward to incorporate them into the system without major changes to the backend servers or services. Currently we are using standard based bluetooth sensor and this can be easily replaced with another bluetooth device. There is clear interface/boundary defined in the gateway device for communicating to the bluetooth sensor on one side and web service communication to the server on the other side. In case there are other sensors available in the market that use UPnP, DPWS or other plug and play technologies, the corresponding module in the gateway can be updated to adapt to this technology without affecting the communcation to the server. If intermediate software components or operating systems are to change, the system is designed in a manner to take care of these changes in a seamless fashion with minimal disruption to the service provided to end users already using the system. The system is flexible to the level of handling different display devices with different screen resolutions and form factor. Using the flash system for presenting the graphs the continuous signals can be easily viewed in most modern mobile devices and computers. We rely on the properties of flash to adapt to different screen resolutions. Thus, for example, the same application can be launched to display to a large console in the nursing home where staff may be able to see it at a distance, as well as to a small hand-held device (PDA) in the hands of a doctor. There will also be a text based report for devices that does not support flash media. Fig 3 shows how the data is presented to the doctor in a 24 hour form as a bar chart (above) and continuous activity signals with zoom-in capability for arbitrary time period (below). These GUIs are targeted to a notebook computer. Essentially the same GUI can be seen in a hand-held device, but with reduced resolution, and some detail removed.

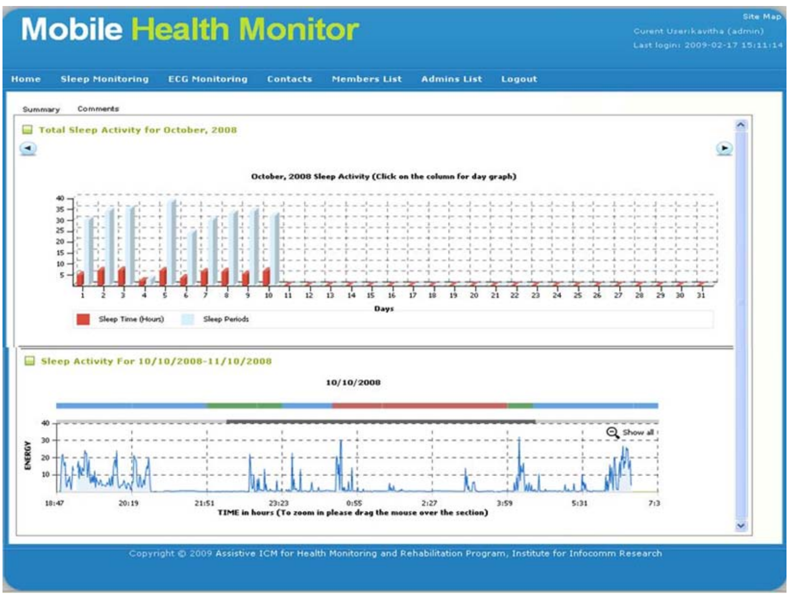

Fig. 3. Twenty four hour sleep data, sleep diary & zoom-in on selected segment

In designing the system to be used in real situations, in nursing homes etc., there were many issues to be taken care of, to allow fault-tolerant and reliable continuous data transfer from sensor to server. In the nursing home, the patient may be out of range from the smart-phone gateway often, especially during day hours. There may be situations where the patients come into the range and go out of range again frequently. There may be connection failures for the connectivity between the phone and the server. There have also been issues on using different bluetooth software stacks. Such scenarios have been considered in the design, to keep the errors within allowable boundaries and to avoid the accumulation of errors.

Data transfer from phone to server and data storage at the server side are some of the engineering issues that were considered. Timestamps were sent with every packet to help reconstruct data at the server side. The system was designed to allow multiple users to connect at the same time. Most of the processing of data is done at the server end. With multiple users connected at the same time, the design also has to avoid bursty processing, to keep the server loading under control. The system offers a web-based end user interface for doctors, patients or care-givers to observe the results remotely. The users are authenticated through the web interface and the system offers different authorization roles for different types of users. For example, doctors can view information for all his/her patients, while care-givers are restricted to just the patients that they take care of. There were other issues in using smart-phone as a gateway. With continuous wireless transmission and processing, the battery power of the phones will drain out within few hours. It was required to power the phones directly from the mains. To minimize power wastage, the program running in the smart-phone controls some of the power management functions.

Using the above prototype we have embarked upon a reasonably large trial involving nursing home residents, charting their patterns of sleeping and active periods and circadian rhythms therein. In a new phase of the project we are looking at respiratory rate monitoring, and possible correlations between sleep activity patterns and respiration. It is expected that this system will benefit both the care-giver and the patient.

5 Design of Algorithms for Processing of Sleep Data

Fig 4(a) depicts the program flow of the algorithm for classification of sleep activity patterns. Since the architecture for data collection involves a link over the wide area network, data is collected in fragments, each fragment being stored in a separate file. Files are allocated identifiers based upon their date and time of creation. A separate file maintains the time stamp of the first and last entries of each file. In this manner it is ensured that even if there is loss of data due to network congestion or packet drop, time information is still maintained in a consistent manner. Fig 4(b) illustrates the

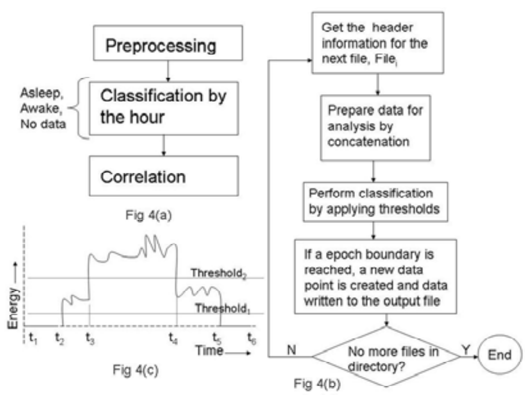

Fig. 4. Algorithms for Processing of Sleep Data

pseudo-code of the algorithm for computing classification based on thresholds of the processed signal data and Fig 4(c) illustrates how the thresholds are applied to signal data based on computed Energy of the movement information from the accelerometer.

6 Results of Trial Deployment and Initial Data Analysis

Functional Assessment Staging of Alzheimer's Disease (FAST) [16] scale is a functional scale designed to assess the severity of dementia. Table 1 gives the assessed FAST scale stage for each resident who participated in the trial. Fig 5 shows plots of the errors recorded via the sensor-reported classification vis-à-vis the manually recorded ground truth, for four randomly selected residents, for the two week trial period. It may be noted that on certain occasions no data was available due to loss of network connectivity or battery outage at the device. Overall, the error rate as reported by actigraphy is between 20% to 30%, however we feel that the reason for this is our inexperience with the proper manner in which to use the device and conduct the data acquisition, rather than an intrinsic problem with the sensing modality (actigraphy) itself.

Table 1. Residents' particulars and FAST scale stage

Case	Age	Sex	FAST stage	Ambulant Status
1	93	F	5	Ambulant
2	89	F	5	Ambulant
3	84	F	7	Non-ambulant
4	75	F	6	Non-ambulant
5	66	F	7	Non-ambulant
6	98	F	5	Non-ambulant
7	93	F	5	Non-ambulant
8	92	F	5	Partially ambulant
9	80	F	6	Non-ambulant
10	81	M	5	Non-ambulant
11	90	M	5	Partially ambulant
12	79	M	4	Ambulant
13	82	M	4	Partially ambulant
14	84	F	5	Non-ambulant
15	83	M	5	Non-ambulant
The FAST scale [16] has seven stages defined as follows:				
1: No cognitive decline			5: Moderately severe cognitive decline	
2: Very mild cognitive decline			6: Severe cognitive decline	
3: Mild cognitive decline			7: Very severe cognitive decline	
4: Moderate cognitive decline				

The histograms in Figs 6a and 6b show the number of times a certain number of sleep periods occurred for a given group of patients. Fig 6a expresses this statistic for those with mild to moderate dementia (FAST grades 4-5), whereas Fig 6b expresses this statistic for those with moderately severe to severe dementia. From these two

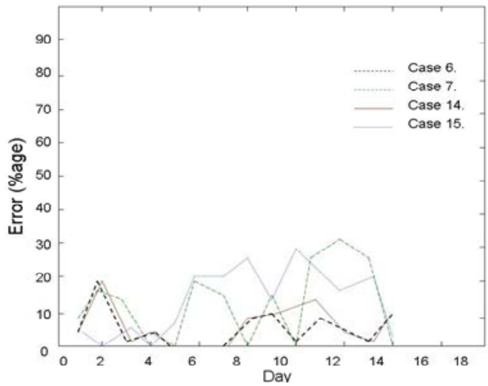

Fig. 5. Overall error - automated against manual recording

plots it can be said that the variability in number of sleep periods is larger in the case of those with more severe dementia. In other words as the stage of dementia progresses, variability in sleep patterns tends to increase and this is consistent with what is known about the disease. The histograms in Figs 6c and 6d show the distribution of daily total sleep time for the same two groups as in Figs 6a and 6b respectively. From these two plots it can be said that the total sleep time is less for those with more advanced dementia (Fig 6d). More quantitative remarks cannot be made at this stage due to lack of adequate data.

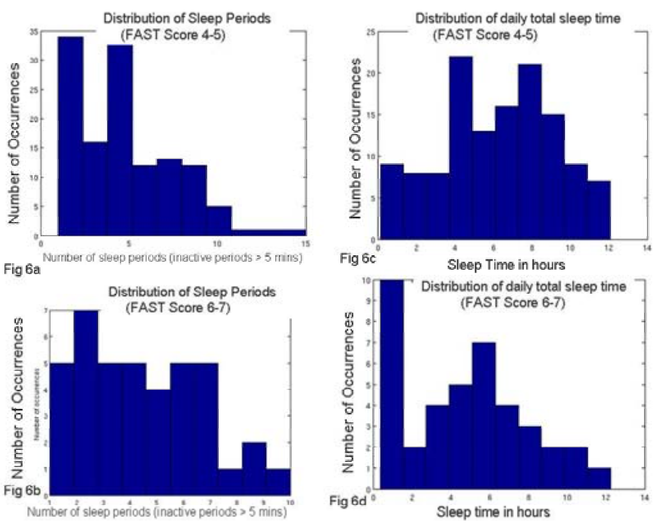

Fig. 6. Sleep periods & total sleep time for moderate & severe dementia patients

7 Summary and Conclusions

In this paper we have presented a sleep activity pattern monitoring system that is built from simple hardware and software in a scalable and extensible fashion. The system was put to use in collecting the SAP of fifteen residents of a nursing home over a period of two weeks each. Several problems identified with the prototype were addressed and eventually the system was able to collect data continuously for long periods of time. We found that the algorithm development for a system such as this can be challenging because of numerous factors and issues that need to be kept in mind so as to make sure that reliable data is being collected when needed, and to put in place mechanisms to check the accuracy and validity of data collected and inferences made, by comparing with manually recorded ground truth. This paper presents some initial snapshots of the sleep data collected for residents with various stages of dementia. Although these results are not conclusive due a relatively small sample size, they point the way towards a methodology for automated collection, recording, summarization and presentation of sleep related data, thereby saving manual effort and improving the quality and effectiveness with which sleep therapy and medical treatment can be carried out. Furthermore, the system-building approach we have adopted lends itself to easy extensibility: additional sensing devices and analytical tools may be incrementally added and exchanged in a straightforward manner without major modifications to the system.

In future work, we plan to test our system in the homes of selected patients with sleep problems, and carry out more extensive data collection to arrive at results that are statistically more robust. One of our goals is to evaluate some means of raising prompts and alerts for intervention and behaviour modification targeted at both the patient and the carer. Future versions of the prototype will address these issues.

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A Rotating Roll-Call-Based Adaptive Failure Detection and Recovery Protocol for Smart Home Environments

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Abstract. Smart homes generally differ from other pervasive environments such as office environments. Homes are lack of system administrators to fix faulty services on the spot. Nevertheless, services in smart homes can be critical especially when they involve health and wellness services, since faulty services can lead to unexpected/undesirable consequences. Therefore, robustness and availability are two fundamental requirements for service management protocols or middleware at homes. In this paper, we propose an efficient and adaptive failure detection and recovery mechanism, namely, the Rotating Roll-Call-based Protocol (RRCP), for home environments. Failures of software components are detected efficiently with a roll-call-based algorithm in which the roll-caller is elected periodically. Adaptive techniques and reliable UDP are adopted to maintain home network stability. Experimental results show that the proposed protocol is robust even under elevated failure rates.

Keywords: failure detection, failure recovery, smart home.

1 Introduction

We can perceive the advent of the next generation computing environment attributed to rapid emerging of intelligent devices and sensors. We believe that, soon after, these technologies will also be brought to our homes. However, technologies are treated differently at homes. Home is a pleasant place where people stay and relax. Activities in offices differ from home activities. Activities in offices tend to be more formal, task-oriented, and geared to optimize productivity, whereas home activities are more informal and for entertaining. In addition, the scale of infrastructure to support social interaction within a home is often reduced to a small LAN (Local Area Network) [1]. Furthermore, another important home feature is that homes are lack of a professional system administrator that can be there anytime to fix software or hardware failures [2]. This can lead to unexpected/undesirable consequences, especially when it comes to health and wellness services. Suppose a fall detection service for the elderly at home is devised, and the service fails without anybody's notice. With the failed service, parents wouldn't know about a falling incident when it occurred, and the time for emergency assistance can be seriously delayed. Therefore, service *availability* and

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robustness are two fundamental requirements for middleware or service management protocols at smart homes.

In [3], we have proposed a Pervasive Service Management Protocol (PSMP) devised to fulfill the requirements when intelligent technologies are brought into home. The functionalities of PSMP include autonomous service composition, activation, failure detection, and failure recovery. In addition, we have also designed a Pervasive Node Application Model (PAM) and dealt with the failure detection and recovery of the Service Nodes, but the failure detection and recovery of Kernel Nodes remain unsolved.

In this paper, we propose a novel approach, called Rotating Roll-Call-based Protocol (RRCP), to detect failures efficiently in the home environment based on PAM. This approach is inspired by the roll-call procedure in our daily lives. For example, the names of people from a list are called one after one to determine the presence or absence of the listed people. In our protocol, every Kernel Node takes turn to initiate a roll-call, and therefore a failed node can be detected rapidly and be marked as suspected. To avoid making false detections, we consider a semi-consensus policy here, i.e., a node is considered as failed only when more than half of the nodes in the environment suspect it.

To achieve better efficiency, we adopt reliable User Datagram Protocol (UDP) as the transporting protocol used. Finally, the time period for calling the roll is adaptive; i.e., it varies depending on context of the network and status of the nodes. This time period is crucial to the failure detection time.

The RRCP is designed based on the Message-based Pervasive middleware and the Pervasive Node Application Model (PAM) presented in [3]. The Message-based Pervasive middleware is supported by the message-oriented middleware (MOM), a "software bus" for integrating heterogeneous service components. The logical pathways between service components are called "topics", which reside in MOM. Service components in MOM exchange messages via several topics. The advantage of the MOM is that the dependencies between nodes are removed: they depend on topics instead of depending on each other. Hence, the failures of nodes in Message-based systems are always isolated. Moreover, when recovering from failure, the order of execution or re-initialization of nodes does not matter.

In the next section we will begin by giving an overview of failure detection protocols. In Section 3, we introduce the Pervasive Node Application Model, which is the base of our protocol. The Rotating Roll-Call-based failure detection and recovery protocol is described in Section 4. Section 5 discusses the implementation details and the performance of the RRCP protocol. Finally, conclusions are presented and suggestions are made for further research.

2 Related Works

Many advanced failure detection techniques in distributed environments have been proposed. Traditionally, a system monitor detects failures by using Periodic-broadcast-based protocols such as Heartbeat or Polling [4]. If the broadcasting period is configured properly, Heartbeat or Polling protocols reduce significantly the failure detection time. However, these protocols usually consume network bandwidth and cause instability in the environment. Recently, Gossip techniques [5] have also become a prominent method to detect failures in distributed environment. However, Gossip techniques are designed for large-scale systems because it is highly scalable, but unfortunately they also introduce considerable detection latency [5].

The aim of this paper is to devise a failure detection protocol that is favorable for home environments. The faulty services can be detected efficiently using a roll-call-based algorithm and a semi-consensus technique. Adaptive techniques and reliable UDP are adopted to maintain home network stability.

3 The Pervasive Node Application Model

Before the detailed discussions of proposed mechanisms, we propose a Pervasive Node Application Model for a message-oriented pervasive middleware (see Fig. 1). In this model, we will use the term "Pervasive Node" to refer to an atomic software entity in a message-oriented pervasive middleware.

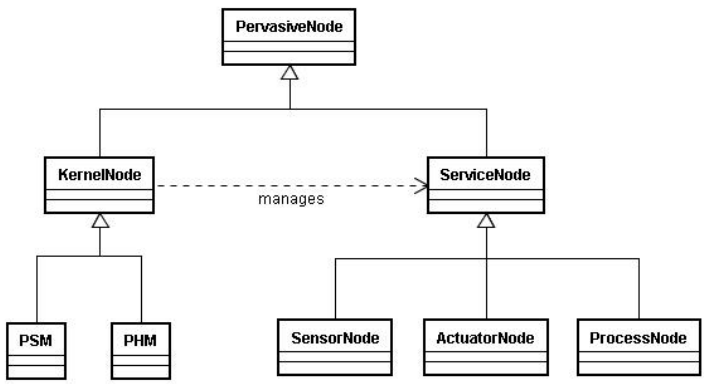

Fig. 1. The Pervasive Node Application Model

As illustrated in Fig. 1, there are two subtypes of Pervasive Node: Kernel Node and Service Node. Service Nodes are the basic component of a pervasive service. We can further classify Service Nodes into 3 sub-categories according to their behaviors: Sensor Nodes acquire context information from the environment, such as temperature sensors; Actuator Nodes perform actions, such as appliance controller; and finally, Process Nodes perform logic operations according to the context gathered by Sensor Nodes and instruct Actuator Nodes to execute the corresponding action.

Kernel Nodes perform administrative tasks as mentioned above. PSM (Pervasive Service Manager) manages the group of Service Nodes of a certain Pervasive Service, such as an adaptive air conditioning service that turns on the fan when the temperature increases. PSM activates and manages its group members according to a PSDL (Pervasive Service Description Language). The PSDL keeps track of the corresponding Service Nodes needed by a Pervasive Service, including their criteria, the number of instances, restrictions, and other information. PHM (Pervasive Host Manager) manages the group of Service Nodes and their lifecycle located in the same machine.

Each Service Node, after installation in the machine, registers its metadata to the PHM's PSMR (Pervasive Service Metadata Registry), so that they can be enquired for. Note that the members of PSMs and PHMs can be overlapped.

The Service Nodes are monitored by PSMs, where the failure detection and recovery of Service Nodes have been discussed in [3]. In that work, the authors assumed that Kernel Nodes do not fail, which is unrealistic. Hence, in the next section we propose a method for Kernel Nodes to monitor one another and detect failure of Kernel Nodes in an efficient way.

4 Rotating Roll-Call-Based Failure Detection and Recovery

In this section, we describe the Rotating Roll-Call Protocol for smart home environments. Although the protocol is based on the Pervasive Node Application Model discussed in the previous section, it is also suitable for any small-scale distributed environment such as the home network where the failure detection latency is critical.

4.1 Failure Detection and Recovery

In our Pervasive Node Application Model, Kernel Nodes are the Pervasive Nodes that manage the Service Nodes. There are two kinds of Kernel Nodes: PHM and PSM. For simplicity, we will refer "Kernel Nodes" simply as "nodes" in the following sections. Nodes can all be distributed in different machines but two or more nodes can also be deployed in the same machine. All of the nodes together constitute a distributed system environment. Therefore, the RRCP can be applied to any distributed environment.

The reference implementation of RRCP is based on UPnP's [6] SSDP (Simple Service Discovery Protocol), which is widely adopt in the Smart Home Environment However, the core concepts of the RRCP can be easily applied to any other Service Discovery Protocol. We use SSDP to receive and send "presence" announcements. Every node will have a list of nodes present in the environment. Note that we assume that the list maintained in every node is the same; however, the order of the nodes in the list can be different. The problem is that the default latency of SSDP's periodic announcement is set to 1800 seconds, although this can be set differently, but too much bandwidth will be wasted if this latency is set too short as SSDP sends 3+2d+k messages for each device. For this reason, here we propose an appropriate method to detect failures reliably and efficiently.

At the beginning, the nodes perform a Leader Election procedure to decide who would be the first leader. For Leader Election, we adopt the Invitation Algorithm [7]. The key idea of the Invitation Algorithm is that a node wishing to become the leader "invites" other node to join it in forming a group. At the beginning, each node is the leader of its own group which contains itself only. Each leader periodically "invites" other groups to join it. To avoid a livelock situation, a priority mechanism is used so that lower priority nodes send out invitation after a longer period of time. For details of the algorithm, see [7].

After the leader is elected, the checking process begins. The message exchange sequence diagram is shown in Fig. 2 and Fig. 3. The leader sends *Check* (CHK) messages to every node in its list via UDP, just like calling a roll. A node that receives a

CHK message must reply with an *acknowledgement* (ACK) telling the leader that it is alive indeed, as in Fig. 2. The leader will wait for a time period for the acknowledgement, and, if a node does not reply, the leader will mark that node as *suspected*.

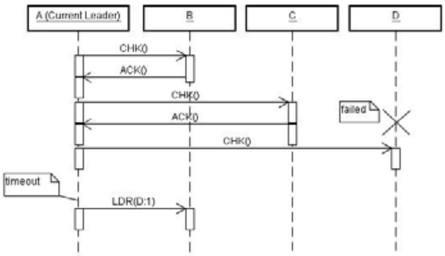

Fig. 2. Node A is the leader and calls the roll. As node D does not reply, it is marked as suspected. A while later, the leader authority is passed to node B.

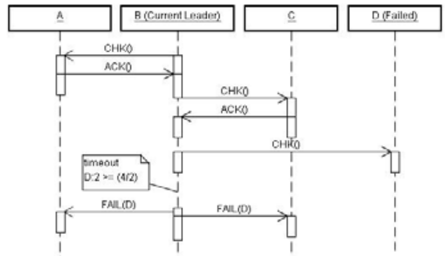

Fig. 3. Node B is now the current leader. After calling the roll, it notices that half of the nodes suspect node D, and therefore it announces node D's failure.

Every node maintains a *suspected list* of nodes, and this *suspected list* is passed along with the leader authority. After calling the roll, the leader must check whether more than half of the nodes in the environment suspect the same node. If there is such a node, the leader announces that this node has failed with a FAIL packet, as in Fig 3. On the other hand, if the leader receives an ACK that is in the suspected list, then the waiting time period for acknowledgement is extended. This time period is crucial as it affects the interval for calling the roll and consequently the latency for detecting a failure. If the leader receives an ACK from a node that is in the suspected list may indicate that the network or the nodes are loaded, and as a consequence, the waiting time is extended. The waiting time period is adjusted again after certain times of normal operation.

Finally, the current leader passes the leader authority with an LDR packet to a random node along with the list of *suspected* nodes and the number of nodes that suspect each of those on the list. The node that receives the LDR packet must also reply with a LACK. This is necessary as the leader authority must not be lost. The purpose of passing around the leader authority is for load balancing. In our Pervasive Node Application Model, every Kernel Node has its own responsibility, and therefore they cannot be performing the leader labor constantly. Table 1 presents a summary of the packets used in the RRCP and their corresponding functions.

The process described above is repeated until none of the nodes receive the leader authority for a certain period of time. This may imply that the node that received the leader authority has failed, and hence the leader election algorithm is carried out again.

The leader that detects the failure of a node is in charge of recovering it. Because Kernel Nodes are irreplaceable, the leader will try to re-execute the software application directly. When a PHM recovers from failure, it must check which are the nodes executing in the host it manages. When a PSM recovers from failure, it must check the nodes which compose that service that it manages.

Table 1. Types of packets used in the RRCP

Packet	Function	Description	Notes
CHK	Check	Sent by the leader when checking every node's status	No retransmission needed. A node is marked as suspected by the leader if no ACK is received.
ACK	Check Acknowledgement	Sent to the leader to indicate that the node is operating properly	
LDR	Leader	Used to pass the leader authority between the nodes	Packet is retransmitted if no LACK is received.
LACK	Leader Acknowledgement	Indicates that the leader authority is received	
FAIL	Failure	Sent by the leader to announce the failure of a node	Packet is retransmitted if no FACK is received.
FACK	Failure Acknowledgement	Indicates that the announcement of failure is received	

4.2 Analysis

We consider a fail-stop model, where nodes stop executing and stop sending messages when they crash. For link abstractions, we assume a Fair-Loss Link. The fair-loss property guarantees that a links does not systematically drop any given message. Therefore, if neither the sender node nor the recipient node crashes, and if a message keeps being retransmitted, the message is eventually delivered [8].

Correctness. A healthy node replies with an ACK when it receives a CHK form the leader. If one of these packets is lost, the next leader will check again, and thus the suspicion is corrected. To avoid false detections, we adopt a semi-consensus technique: the suspected node is considered failed only until more than half of the nodes suspect it. This will avoid every node makes its own decision, and comes to an agreement from the majority of the nodes.

Performance. The algorithm proposed here can reduce failure detection time as a faulty node can be detected quickly after half of the nodes suspect it. The suspecting message does not need to gossip among random nodes and it does not need to wait until all of the nodes come to an agreement. The algorithm does not consume too much bandwidth as it uses reliable UDP instead of broadcast mechanisms. This transforms many-to-many communication into one-to-many communication.

5 Implementation and Evaluation

We have implemented a prototype of our Adaptive Failure Detection and Recovery Protocol. All nodes are randomly distributed over three P4/1GHz mini-PCs in the same LAN with 1G bytes memory. We designed experiments to investigate the *availability* and *efficiency* of our protocol. At the beginning of the experiment, an initial configuration is established: all the Pervasive Nodes, including Service Nodes and Kernel Nodes, discover each other and operates properly. During the experiment duration, a number of Kernel Nodes fail at the same time. The node failure rate varies from 10% to 80% in 10% increments. Our experiment models a prototype that includes 10 Kernel Nodes, composed of 5 PHMs and 5 PSMs.

5.1 Metrics

We investigate the *availability* and *efficiency* of our RRCP. According to [9], availability can be defined as below:

$$\text{Availability} = \text{MTTF} / \text{MTBF} = \text{MTTF} / (\text{MTTF+MTTR}) \ . \quad (1)$$

MTTF is the Mean Time To Failure, MTBF is the Mean Time between Failures, and MTTR is the Mean Time To Repair. Therefore, to achieve high availability, we must minimize the MTTR. The value of Availability depends greatly in MTTF, and the longer we set the experiment duration, the higher will be the availability. Hence, here the value of MTTR is more meaningful. MTTR measures the latency from the failure of the first node until all the nodes are recovered and the initial configuration is restored. We decompose MTTR into failure detection and failure recovery latency. Efficiency is measured as the total number of messages required to detect and recover a failure.

5.2 Experiment Results

We executed 80 repetitions, 10 repetitions for each failure rate. The results of the experiments are shown in Fig. 4 and Fig. 5. We can notice a slight decrease in message counts whereas an increases in the failure rate. This is because with more suspected nodes, fewer nodes reply with the CHK packets and semi-consensus is achieved faster. However, the message counts for failure recovery increase with the failure rate, as nodes exchange SSDP presence announcements during the recovery procedure. Comparing the experiments done in [10] which show the message counts of UPnP SLP and Jini, messages counts are considerably reduced in our protocol. But for availability, it is incomparable as experiments settings are different.

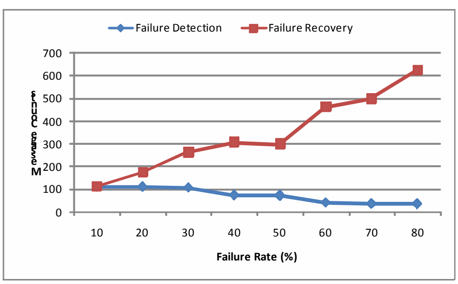

Fig. 4. Message Counts for Failure Detection and Recovery

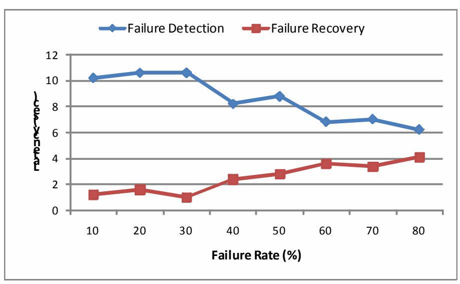

Fig. 5. Latency in seconds for Failure Detection and Recovery

The diagram in Fig. 5 shows that the failure detection latency decreases with failure rate. This is due to the fact that with fewer nodes it is faster to reach an agreement among half of the nodes. The latency of failure recovery is higher as failure rate increases, this is because more nodes need to be discovered by each other during the recovery procedure and thus longer time is taken.

6 Conclusion

Availability is one of the most important aspects for a middleware or service management protocol. System availability is usually defined as the portion of system uptime over the sum of uptime and downtime [11]. Therefore, a service management protocol in smart home environment should be designed to decrease or minimize the downtime of a system. In this paper, we propose an adaptive failure detection and recovery protocol that is suitable for any small-scale distributed environment where the failure detection and recovery time are critical. Experimental results show that the proposed RRCP is robust even under elevated failure rate. Currently, we use SSDP for service discovery, but from the experiments we learned that the message counts of SSDP increases considerably with the number of nodes. We think this is due to the multicast mechanism used by SSDP. We are therefore planning to design a more efficient service discovery protocol for our Service Management Protocol for Smart Homes in the coming future.

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Fall Detection and Alert for Ageing-at-Home of Elderly

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Abstract. Fall detection has been an active research problem as fall detection technology is critical for the ageing-at-home of the elderly and it can enhance life safety of the elderly and boost their confidence of ageing-at-home by immediately alerting fall occurrence to care givers. This paper presents an algorithm of fall detection for the ageing-at-home of the elderly. This algorithm detects fall events by identifying (human) shape state change pattern reflecting a fall incident from video recorded by a single fixed camera. The novelty of the algorithm is multiple. First, it detects fall occurrence by identifying the state change pattern. Second, it uses the camera projection matrix in its computing. Thus, it eliminates camera setting-related learning. Lastly, it adds constraints to state change pattern to reduce false alarms. Experiments show that the proposed algorithm has a promising performance.

Keywords: Assistive Technology, Ageing-at-Home, Fall Detection, Camera Calibration, State Change Pattern.

1 Introduction

Assistive technology for *ageing-at-home* has become a hot research topic as such technology has big social and commercial value. As you may agree, ageing-at-home has multiple benefits. First of all, when the elderly stay at their own homes they will live happier than in nursery as they stay in their familiar environment without changing living style. More importantly, they can stay with their family. Second, ageing-at-home saves their living cost and reduces the demand on public facilities for elderly care. Lastly, it also alleviates the shortage of nurses and the financial burden of governments. On the other hand, the elderly may expose to risk of fall accidents without the immediate aid when neither nurse nor technology can monitor their activities. The statistics done by governments show that high percentage of injury-related hospitalizations for seniors are the results of falls. Luckily, fall detection technology can assist the elderly to lead an independent living. Fall detection technology will lift the confidence that the elderly lead an independent living. This is because that it will make sure that the victims of fall will get the immediate aid and treatment. The immediate

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treatment of the people injured in falls is critical in saving their life and reducing their suffering. Hence, we should alert the fall incident as soon as possible if falls cannot be absolutely avoided. In these years fall detection has become one of hot research problems in assistive technology development as fall is a type of very critical events that threaten the independent living of the elderly [1-10]. The goal of fall detection technology is to detect fall occurrence as soon as possible and to alert the givers of elderly care.

Many efforts have been made in fall detection due to the big demand and the big potential market value of fall detection technology. Our survey paper [10] has given a summary of the existing approaches and principles of fall detection. From this survey, we can also conclude that the existing technology has not met the requirement of users. In developing the fall detection technology, the computer vision has its irreplaceable role in monitoring people activity, detecting events, and recording video for the post verification [1-10]. There were two main groups of algorithms in vision-based fall detection, i.e. inactivity detection and (*body*) shape change analysis.

The group of inactivity detection uses the principle that a fall will end with an inactivity period. Nait-Charif and McKenna [6] uses omni-camera in the system. The algorithm overhead tracks a person to obtain the motion traces of the person. Then it classifies the activities based on the motion traces and context information. Inactivity is one of classes and an *inactivity* will be said to be a fall if it occurs in certain context. Jansen and Deklerck [4] uses a stereo camera for fall detection. They use the stereo camera to acquire depth image (*called 3D image in their paper*). Then they identify the body area and find the body's orientation. Finally they use the orientation change of body to detect inactivity; fall is detected if inactivity occurs in certain context.

Algorithms in *shape change analysis* group use the principle that the shape of a falling person will change from standing to lying when falls start from walking or standing. B. U. Töreyin *et al* [9] presented an HMM (*Hidden Markov Model*) based fall detection algorithm. In this paper an HMM uses video features to differ fall from walking. The features are wavelet coefficients of the ratio of height to width of the bounding box of body shape. Another HMM uses audio feature to differ falling sound from talking. D. Anderson *et al* [1] uses an HMM–based algorithm to detect fall. The HMMs use the multiple features extracted from the silhouette: height of bounding box, magnitude of motion vector, determinant of covariance matrix, and ratio of width to height of bounding box of human shape. The HMMs are trained to distinguish walking, kneeling, getting-up, and falling. Thome and Miguet [8] uses a HHMM-based algorithm to detect fall. The single feature of *hierarchical* HMM is the orientation of the blob of the body. The state-level of HHMM is the postures of a body. The other two levels of the HHMM represent behavior pattern and global motion pattern respectively. S. G. Miaou *et al* [4] use the rule-based algorithm to detect falls. The rules infer the fall occurrence based on the ratio of width to height of the bounding box of body in image. Other points are that it uses the omni-camera and it also uses the context information in deciding fall. R. Cucchiara *et al* [2] uses 3D shape of body to detect fall. 3D body shape is obtained by multiple cameras that are calibrated in prior. Hsu [3] used deformable triangulations of body shape to classify the postures of people (one of the classes is fall), in which body shape is extracted from depth images.

In this paper, we propose a fall detection algorithm, which detects fall by identifying the state change pattern of human shape and shapes are extracted from video captured by a fixed camera. This algorithm combines the merits of both inactivity detection and shape change analysis. One of its steps is to identify the inactivity presence. And our state change pattern is to capture the main characters of human shape change. Compared with "inactivity" algorithms, this algorithm detects more states and also considers the transit relation of states. Compared with existing shape-change-analysis algorithms, our algorithm uses state change pattern to capture more features of fall. And it uses the projection matrix to help state detection.

The rest of this paper is organized as follows. Section II gives the overview of our fall detection algorithm. Section III presents the procedure of the projection matrix acquisition. Section IV presents state detection and state change pattern detection. Section V gives the experimental results. We conclude the paper in section VI.

2 Overview of Fall Detection Algorithm

In this paper we present an algorithm for detecting fall by detecting shape state change pattern and shapes are extracted from video recorded by a fixed camera. The block diagram of the algorithm is given in Fig 1. When a person falls from standing or walking, fall events will undergo *human shape state change* from standing to bending to lying which contains an inactivity, i.e. three shape states in time order. In addition, both bending and lying have its time constraints. Our algorithm not only combines the inactivity detection and shape change detection, but also explicitly introduces the time constraints for shape state transit. Our algorithm does not target to get accurate human shape; instead it targets to get three shape states: standing, bending, and lying.

The features for shape state classification are the trunk ellipse in each frame. In this paper, we assume that we have already got the ellipse in each frame. To classify the shape state we have to segment out the body shape and extract the features of the shape for each frame. Through observation, we find that the fall incident has closer relation with trunk shape than whole body shape. As such, we trim the limbs of body and use ellipse to fit the human trunk. The sizes of trunk ellipses are affected not only by the body shape but also its location in image due to camera projection. In order to alleviate the effect of camera projection, we do camera calibration to obtain the projection matrix. We compensate the effect by estimating the standing height at each image pixel using camera projection matrix. Then based on the trunk ellipses and project matrix, we classify the states of human shape into standing, bending, and lying. Based on the detected states in frames, we identify the state change patterns that reveal fall incidents.

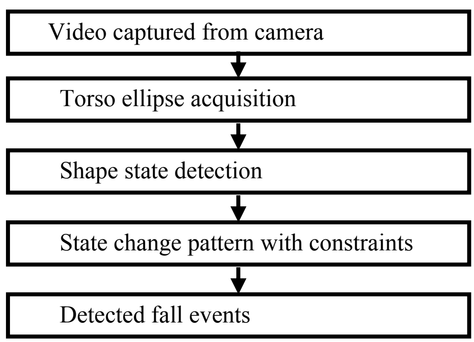

Fig. 1. Flowchart of our algorithm for fall detection based on the shape state change detection using single fixed camera

3 Camera Calibration

In our algorithm, we need the camera projection matrix to compensate the size variance of the same shape due to different locations in the same image. As such we first present how we get the projection matrix that will be applied to our algorithm.

3.1 Projection Geometry

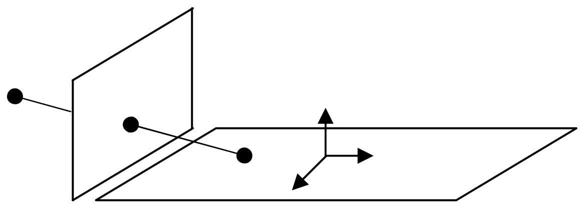

Fig. 2. The Euclidean transformation between the real world and the image space for the video recorded by pinhole camera

Expression (1) shows the Euclidean transformation between the real world and the image space for the video recorded by pinhole camera, by camera C in Fig 2. The real-world point is represented by *w*, a homogenous 4-vector $(X, Y, Z, 1)^T$, *m* for the image point represented by a homogenous 3-vector $(x, y, 1)^T$, and P for the 3x4 camera projection matrix. Then for a basic pinhole camera, the mapping between the 3D world and the 2D image is written compactly as

$$m \cong \mathrm{P}w \tag{1}$$

where $\cong$ means that two sides can differ by an arbitrary scale.

3.2 Procedure of Camera Calibration

Expression $m \cong \mathrm{P}w$ is an equation involving homogeneous vectors, so m and $\mathrm{P}w$ need only be in the same direction, not strictly equal. Hence, we have the relation: $m \times \mathrm{P}w = 0$. That means that one correspondence can derive the following two equations.

$$\begin{bmatrix} 0^T & -u_i \mathrm{w}_\mathrm{i}^T & y_i \mathrm{w}_\mathrm{i}^T \\ u_i \mathrm{w}_\mathrm{i}^T & 0^T & x_i \mathrm{w}_\mathrm{i}^T \end{bmatrix} \begin{pmatrix} \mathrm{P}^1 \\ \mathrm{P}^2 \\ \mathrm{P}^3 \end{pmatrix} = 0. \tag{2}$$

Here $m_i = (x_i, y_i, u_i)$ and w_i are a correspondence between image point and world point. $P^i = (p_{i1}, p_{i2}, p_{i3}, p_{i4})$ and $P = (p_{ij})_{3\times 4}$. If we have a set of correspondences, we have the following linear system.

$$\mathbf{Ap} = 0 \tag{3}$$

Since $\mathrm{P} = (P^1, P^2, P^3)$ has 12 elements but 11 free variables, we can determine P by *five and half* correspondences between the image and the real world. However, we normally use more than six correspondences to over-determine projection matrix.

4 Fall Detection Based on Shape State Change

Now we want to detect the shape states and shape state change pattern using the trunk ellipse of each frame. We assume that the trunk ellipse of each frame is known. Then we emphasize the procedure that detects fall based on trunk ellipses. Here we divide the shapes into three states: standing, bending, and lying. Then we use state change pattern detection to identify fall events.

4.1 Human Shape State

Let F_1, F_2, F_3, …, F_{W-1}, F_W be W frames in our considering time window and F_W be the current frame. We use $(a_i, b_i, x_i, y_i, \theta_i)$ to be the trunk ellipse of frame F_i for i=1, 2, …, W. Then based on these ellipses we detect the shape state of each frame. We divide the human shapes into three states:

Standing: Considering frame F_k we judge whether person is standing by evaluating five consecutive frames within the concerned time window (*the frame rate is 25 fps*). We use H_i to denote the estimated human height when his shape center is at (x_i, y_i) .

We can say that the person is standing at frame F_k if it meets the following condition

$$\frac{|H_i - a_i|}{H_i} < \beta_{stdh} \text{ and } |\theta_i - \frac{\pi}{2}| < \beta_{stda} \text{ for k-2} \le \text{i} \le \text{k+2} . \tag{4}$$

In this paper β s are all kinds of thresholds.

Lying: We can say that the person is lying at frame F_k if it meets the following condition

$$\frac{|H_i - a_i|}{H_i} < \beta_{lyh} \text{ and} |\theta_i| < \beta_{lya} \text{ and} |\pi - \theta_i| < \beta_{lya} \text{ for k-2} \le \text{i} \le \text{k+2} \tag{5}$$

Bending: Currently all other cases are classified as bending. In our future work we will further divide this group into bending, crouching, etc.

We first identify the standing-bending-lying occurrences. Then we further evaluate whether such an occurrence is fall by checking constraints. The first constraint is that bending duration must meet certain condition. In a fall, the head would incline from standing to lying down. We use B to denote the number of frames of bending. Then

$$\beta_{\min b} < \text{B} < \beta_{\max b} \tag{6}$$

The second constraint is that person must lie down for a period of time and inactivity for a period of time. We use L to denote the number of lying frames and I for inactivity. Then

$$\text{L} > \beta_{lying} \quad \text{and} \quad \text{I} > \beta_{ina} \tag{7}$$

In addition, we have another constraint through observing fall incidents. That is, during a fall foot locations are within a circle centered at the foot location of the last standing frame. Foot location is inferred from trunk ellipse. P_i denotes the foot location in frame i and P_s denotes the foot location of the last standing frame. Then we have the following constraint

$$|P_i - P_s| < \beta_{foot} \quad \text{for } i=0,1,\ldots,m. \tag{8}$$

where m is the frame number from the last standing frame to the first frame of the inactivity.

4.2 State Change Pattern with Constraints

State change pattern detection is common approach in fall detection and other event detection. Constraints are essential in identifying state and pattern. However, to the best of our knowledge no fall detection algorithm uses state change pattern with constraints yet. As we can see separating some constraints from state definition will bring us convenience and efficiency. Obviously, a fall will undergo standing, bending, and lying when a person falls from standing. But not all such state change patterns are fall. We can add constraints on such state change patterns to discard some patterns that do not connect with the fall event. Our proposed state change pattern with constraints is depicted in Fig 3.

The three states and three constraints are defined in the preceding section. C_1, C_2, and C_3 correspond to the constraints given in equation (6), (7), and (8). Based on our fall detection algorithm, we form the following fall detection and alert framework.

Framework 1: Fall Detection and Alert Framework

Step 0, Initialization:

Load the camera projection matrix;

Prepare space for all data in a sliding window.

For a new frame do

Step 1. Shape State Detection

Subtract the background; obtain the trunk ellipse; shape state detection.

Step 2. Fall Detection:

Standing-bending-lying event detection;

Filter false falls using the constraints.

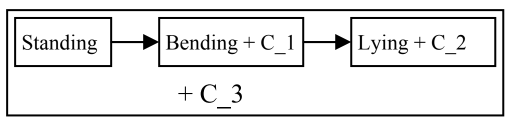

Fig. 3. State change pattern with constraints for fall detection for the elderly

Step 3, Fall Report:

Broadcast an alert if a fall is detected and achieve the corresponding clip for post verification.

Here we assume that the projection matrix is obtained before running our algorithm. For fall alert, we have implemented and tested fall alert component. We use *Multimedia Messaging Service* to broadcast alerts to subscribers. Each alert contains the text description of the fall and a short video clip for remote verification.

5 Experimental Results

We test our algorithm presented in this paper on seven mock-up video sequences, mainly recorded in our A*Star smart home (Here "mock-up" means that falls are

Table 1. Performance of state detection and fall detection

	#F	State Detection (Detected/Total)			Fall Detection			
		standing	Bending	Lying	#T	#D	#A	#M
1	502	153/291	280/81	69/84	6	4	0	2
2	1400	116/449	1059/678	225/221	7	8	2	1
3	414	38/136	187/86	144/192	2	1	0	1
4	8707	2597/6064	5195/2137	381/422	11	9	0	2
5	1196	255/483	597/381	343/331	17	16	0	1
6	1599	259/707	968/550	293/266	11	9	0	2
7	1490	179/611	890/510	421/369	9	9	0	0
+	**15308**	**3597/8741**	**9176/4423**	**1876/1885**	**63**	**56**	**2**	**9**

performed by healthy persons). The video resolution is 320X240 at 25 fps. We test our algorithm in two respects: state detection and fall detection.

In fall detection, we say that we correctly detect a fall if our algorithm reports one or more times for a real fall occurrence. In the tested seven sequences, our algorithm achieves above 90% overall recall. The more detail results are summarized in table 1. In Table 1, "#F", "#T", "#D", "#A", and "#M" stand for the number of total frames, the number of total falls in each video, the number of the detected falls, the number of false alarms, and the number of missing falls, respectively. Currently our fall detection has a high accuracy. False alarms are mainly because person suddenly sit on the floor and incline on the sofa. For such case we will use context to reduce such false alarms by combining the scene recognition and object recognition. After we check the missing falls, we discover that we miss some falls because these falls do not have an inactivity period in lying. Such missing is arguable. Maybe it is because the healthy person is more active than the real victim of fall. Such missing shows that to collect the video of real falls is a very important task. Another kind of missing falls are due to that person falls along the camera projection axis. This case reveals the demerit of single fixed camera, especially when camera angle is close to 45 degree. However, such case can be solved by making sure each point has two cameras to cover it. Our idea is to use multiple cameras. But we do fall detection using video recorded by single camera in most cases to reduce the cost of communication among different cameras.

6 Conclusions and Future Work

We have presented a fall detection algorithm for single fixed camera, which achieves a promising performance in both accuracy and recall. Its principle is to detect shape state change pattern with constraints reflecting fall incident. The contributions of the algorithm are multiple. First, it combines both shape change and inactivity detection into state change pattern detection. Second, it proposes a constrained state change pattern approach for fall detection, which enhances the accuracy of fall detection. Lastly, it proposes to use camera projection matrix to improve state detection. With projection matrix, our algorithm can be applied to different settings of camera without setting-related learning.

Three of many other future jobs remain to be done. First, for fall detection we want to further study the relation between states and other activity to improve the accuracy of our fall detection algorithm and extend our algorithm to detect fall and other activities. Second, we will further study how to improve the human detection and tracking performance and how to robustly detect trunk ellipse. Third, we will do field test and improve our algorithm based on end-user inputs.

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ADL Monitoring System Using FSR Arrays and Optional 3-Axis Accelerometer

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Abstract. This paper deals with Activities of Daily Living (ADL) Monitoring System. The proposed system takes into account deploying in real home. The important issue in deployment is the noninvasiveness. That is, the user should not feel inconvenience. Therefore, our system has been developed by making use of FSR sensors and an optional small body-activity sensor. In particular, FSR sensor is a typical noninvasive sensor since it has a shape of film. In order to make a light-weight monitoring system, we use as small number of sensors as possible. And we adopt rule-based ADL inferring algorithms to avoid inconvenience in collecting training data for supervised learning. For the purpose of improving the accuracy of occupation/usage detection, we make FSR sensors into FSR array sensors. We evaluate the proposed system in laboratory and real home environment.

Keywords: activity monitoring, ADL, FSR array, 3-axis accelerometer.

1 Introduction

The elderly population increases faster and faster (6.9% in 1900, 10.0% in 2000, 28.1% in 2100) according to [9]. The ability of the elderly in carrying out ADL decreases and they are more often exposed to chronic diseases and emergency situations like falls as they get older. Especially, the fact that the elderly prefer living in their own homes to institutionalized care augments the demand for the health monitoring of the elderly in home [5].

In recent, the advancement of sensors and wireless communications technology accelerates the development of pervasive health monitoring system in home [5]. Especially, many researchers have focused on human activity monitoring. Body-activity monitoring [1] [4] [6] and ADL monitoring [2] [3] [5] [8] [10] are the two main topics. Here, we mean body-activity as subject's postures (sitting, standing, lying, etc.) and motion (walking, running, stand-to-sit, sit-to-stand, fall, etc.). ADL is the higher level activity and tends to be of more interest to medical staffs than body-activity [7]. The examples are sleeping, having a meal, taking a rest, using a toilet, etc. However, the body-activity monitoring is not sufficient for the purpose of observing how well the elderly live their safe and independent lives.

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For instance, it is not capable of monitoring whether they have a meal regularly, whether they have enough sleep, etc. [5]. Thus, in recent, the ADL monitoring has received more spot light than the body-activity monitoring. Also researches aiming at deploying in real home are increasing [2] [5] [8] [10]. In order to deploy a monitoring system in home, it should be noninvasive. [2] has users wear pendants with RFID to check where they are. [8] makes use of more than 70 simple state change sensors. The sensors observe the opening status of doors or ON/OFF states of appliances. [10] utilized anonymous and binary sensors. This means that the sensors do not identify the user and detect two states such as ON/OFF. They are motion detectors, break-beam sensors, pressure mats, and contact switches. Additionally, RFID tags are used to detect who enters a space. Many activity recognition techniques take advantage of supervised learning. For the purpose of supervised learning, collecting training data is required and it requires long time and self-logging or video surveillance. In order words, collecting training data tends to be invasive even though sensors themselves they adopt are noninvasive.

Another issue in deploying is real-time monitoring by a low computing power system. When we take this into consideration, the amount of sensor input to an activity inferring algorithm needs to be as small as possible. This is because as the amount of input increases, the complexity of the algorithm increases and a high computing facility is required.

We present an ADL monitoring system using FSR sensors and an optional body-activity sensor with to monitor ADLs in noninvasive manner and in real-time. As for the body-activity sensor, we adopt a 3-axis accelerometer. 'Optional' means that the body-activity sensor may be excluded when a user does not want it since the exclusion does not affect inferring activities which involve FSR sensors. The proposed system is noninvasive since it utilizes FSR sensors and small wireless communication modules. In order to improve the detection accuracy, FSR sensors are arranged in the shape of array. That is, FSR array sensors are taken advantage of. The proposed monitoring system classifies 10 activities by using only five FSR array sensors and a single body-activity senor. Among them, seven activities are ADLs. In order to be proper for real-time monitoring with a low computing power system and to avoid hard process of collecting training data, simple rule-based activity inferring algorithms, which exploit small number of sensor input data, are adopted.

The rest of the paper is organized as follows. Section 2 describes the proposed ADL monitoring system. Also, the design principles of FSR array sensor for sleep recognition and sleep inferring algorithm are explained in detail. Experimental results and conclusions are given in sections 3 and 4, respectively.

2 ADL Monitoring System

2.1 System Structure

The structure of the proposed ADL monitoring system is given in Fig. 1. The measured data of FSR array sensors and a body-activity sensor are transferred wirelessly to sensor adaptor. The sensor adaptor distributes sensor data to the corresponding activity inference modules according to their sources. This means that not all the sensor data is distributed to all of the activity inference modules. For example, only the data of a sleep mat (FSR array) sensor is transferred to a sleep inference module. In order words, the sensor adaptor carries out a kind of feature selection.

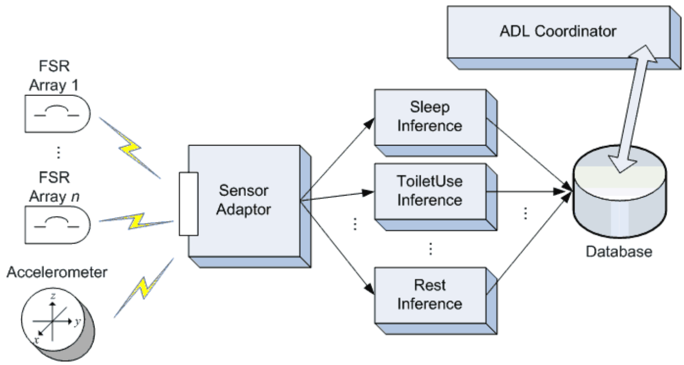


Fig. 1. System structure

Then, each activity inference module carries out inference independently. Reducing the number of input data in inferring activity makes the complexity of each inference module low. Finally, the inferred activity is stored into a database. Independent executions of ADL inference modules may cause conflicts. For instance, when a user takes off clothes to use a toilet, the impact may happen to the body-activity sensor. In this case, 'fall' and 'using a toilet' ADLs may be inferred at the same time. ADL coordinator post-processes this problem.

2.2 Sensors

The sensors the system utilizes are given in Fig. 2. Fig. 2 (a) shows an FSR array sensor for sleep mat. As shown in the figure, the FSR array sensor is produced by arranging 5.5cm x 5.5cm FSR sensors in array. Array arrangement is adopted to solve the low detection accuracy problem when using a single FSR sensor. Note that the sensors in each column are connected. The reason is to minimize the number of input data. The other FSR array sensors are produced in a similar manner.

Fig. 2 (b) shows RF transmitter/receiver modules. They are a receiver module (top), a (FSR array) transmitter module (middle), and a body-activity sensor module (bottom), respectively. A single receiver module is installed to a ADL monitoring system. Theoretically, the receiver can receive 256 data simultaneously. The transmitter modules measure FSR array sensors and transmit the measured data. The body-activity sensor module embeds 3-axis accelerometer (MMA7260q). It is putted on a user's waist and recognizes his/her movement, still, lying, and fall (at instant time).

(a) (b)

Fig. 2. Sensors: (a) FSR array sensor and (b) transmitter/receiver modules

2.3 ADL Inference

The system has seven ADL inference modules: sleeping, using a toilet, having a meal, taking a rest, going out, (long-term) movement, fall (as ADL). Each inference module utilizes only feature-selected data from the sensor adaptor and is based on a simple rule-based algorithm. For example, if the pressure interaction from a meal mat (FSR array) sensor has been detected and its duration is longer than a pre-specified time, the meal inference module recognizes ADL 'having a meal'. In other words, by using only pivotal sensor information for inferring each ADL, the inferring algorithm is simplified. Pivotal sensor information for each ADL inference module is the following: sleeping - sleep mat sensor, using a toilet - seat mat sensor on top of and foot mat sensor in front of a toilet bowl, having a meal - meal mat sensor, taking a rest - sofa mat sensor, going-out - body-activity sensor, (long-term) movement - body-activity sensor, and fall (as ADL) - body-activity sensor. Though the actual ADL inferring algorithms may be more complex, the idea itself for inferring ADLs is simple. Thus, we substitute detail explanation about inference modules (except sleep inference module) with the above. The experimental results in section 3 show the adequacy of the simple rule-based inferring algorithms.

Sleep Inference Module. This module has more input and more complex than the other ADL inference modules. To begin with, the background of the sleep mat sensor design is the following. In order to recognize 'sleeping', 'lying' and 'sitting' need to be discriminated. As a matter of course, the more the FSR sensors are used, the easier the detection is. However, for the purpose of light-weight inferring algorithm, we need to reduce the number of inputs. But, if we detect only part of bed with too small number of FSR sensors, the range of detection gets limited, thereby deteriorating the accuracy. The requirement and constraints above are taken into account in designing FSR array sensors like the sleep mat sensor in Fig. 2 (a). The FSR sensors in each column cover the full range of width and the number of input data is reduced by connecting the

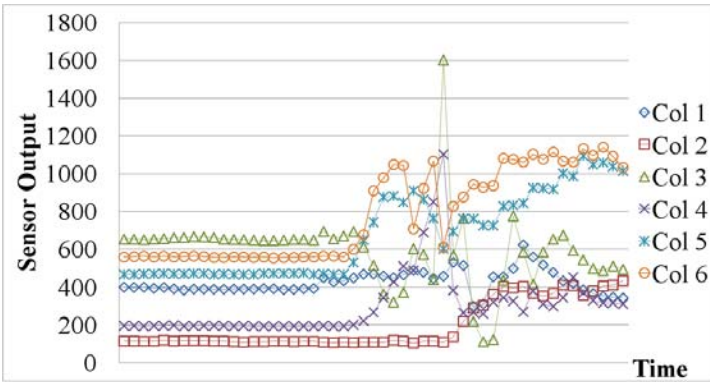


Fig. 3. Raw data of Sleep mat (FSR array) sensor

FSR sensors, thereby being treated as a single FSR sensor. Six FSR columns are used for the sleep mat, which are enough to discriminate 'lying' from 'sitting' of adults.

Fig. 3 shows the raw data of the sleep mat sensor. It is captured during real sleeping. A FSR sensor is a resistor in itself. It has low value for high pressure. As shown in Fig. 3, the variation of sampled values is wide with columns. Consequently, we cannot apply the same threshold to raw data of each column to decide ON/OFF status. We exploit normalization. After normalizing into [0, 1], the same threshold is applied.

Detected ON/OFF statuses of columns are used to discriminate 'lying' from 'sitting'. Through lots of experiments, we found that 'lying' makes at least two columns with one interleaving column ON simultaneously. For instance, at least columns 1 and 3, or columns 2 and 4 are ON for 'lying' activity. This is because most pressure tends to be concentrated around shoulder (including head) and waist.

Next, if the duration of 'lying' is greater than a pre-specified interval (min_sleep_duration), the activity is a candidate for 'sleeping'. We take into account core sleep time (core_sleep_time) where a user is in 'sleep' status in most cases. If the candidate sleep has overlap with core sleep time, it is decided 'sleeping'. This increases the accuracy of inference. Besides, when a user has a slim body (and lies laterally), sometimes only one column has ON status for some time even during sleep. This may incur changing 'sleeping' into 'taking a rest'. Since the duration is short, we can detect it and link separated 'sleepings' by using interval threshold (max_one_on_duration).

The core rules for sleep inferring algorithm are given below. Here, 'disconnect' means that the sensor's 'lying' signal does no longer come in. And hence, the inference module finishes the current inferring process (if 'sleeping' has been determined, it determines the end time of 'sleeping') and goes into idle state.

```
<Sleep inference rule>
If  (‘core sleep time’ && duration(‘lying’)>min_sleep_duration)
Then    ADL ‘sleeping’

<Disconnect decision rule>
If  (duration(no sensor input)>max_disconnect_duration) ||
      (duration(continuous one sensor ON) > max_one_on_duration))
Then    ‘disconnect’
```

3 Experimental Results

In this section, we evaluate the proposed system. Test environment is the following (see Figs. 2 (a) and 4): i) a sleep mat sensor is installed on top of a mattress (Fig. 2 (a)), ii) a meal mat sensor is installed on top of dining table (Fig. 4 (a)), iii) a sofa mat sensor is installed on top of a sofa (Fig. 4 (b)), iv) a toilet seat mat sensor is installed on top of a toilet bowl (Figs. 4 (c)), v) a toilet foot mat sensor is installed in front of a toilet bowl (Fig. 4 (d)), and vi) a body-activity sensor is put on a user's waist (Fig. 4 (e)).

We have simulated ADLs of daily life for experiment purposes. This means that the running time of each activity is shortened. The activities we simulated are sleeping, using a toilet, having a meal, taking a rest, long-term movement, going-out, and fall. They are iterated ten times.

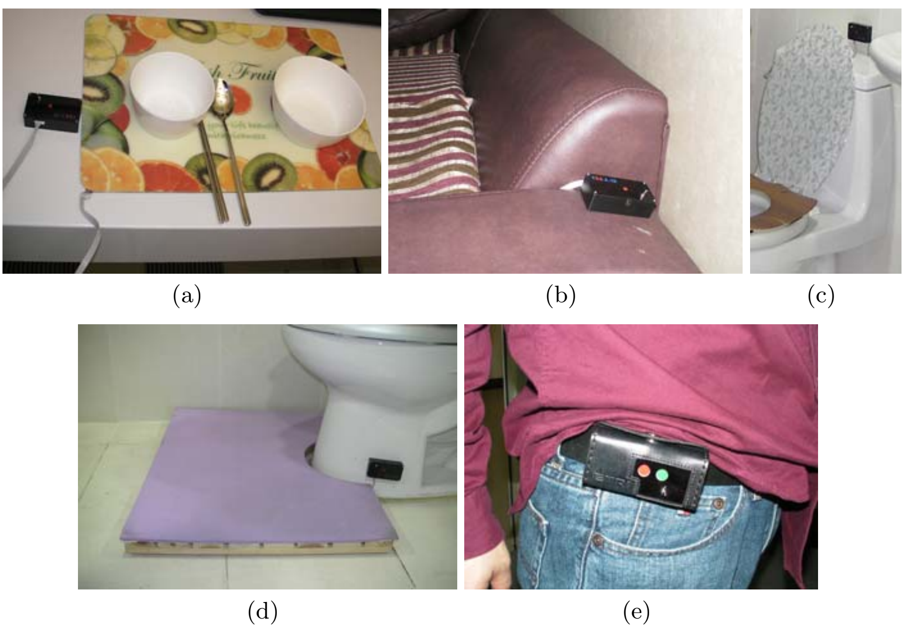
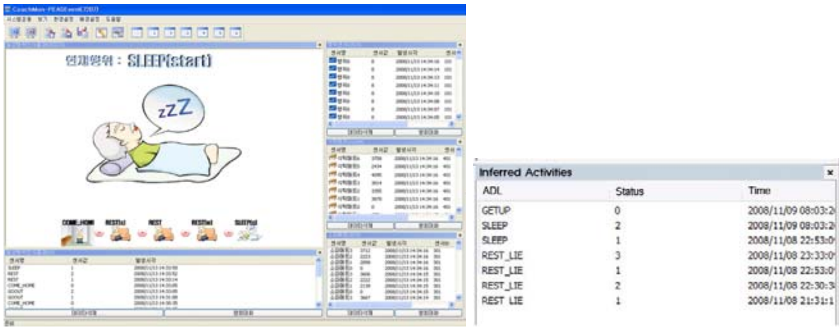


Fig. 4. Test environment: (a) meal mat sensor, (b) sofa mat sensor, (c) toilet seat mat sensor, (d) toilet foot mat sensor, and (e) body-activity sensor



(a) (b)

Fig. 5. Snapshots of (a) the proposed ADL monitoring program and (b) sleep and rest (lie) discrimination

Fig. 5 (a) shows the snapshot of the proposed ADL monitoring program. The left part of the figure shows the current inferred ADL and the right part shows the sensor information. In the experiment, the proposed system exactly inferred all the simulated ADLs. The result shows that it is proper to adopt the simple rule-based ADL inferring algorithms using their pivotal sensor inputs.

As mentioned in section 3, the sleep inference is rather complex than the other ADL ones. Thus, we decided that the system needs to be evaluated in real home environment. A sleep mat sensor, a receiver module, and a laptop running an ADL monitoring program were installed in a real home. A user is not aware of the arrangement of FSR sensors in the sleep sensor and has taken usual sleep. The experiment has been conducted for six days. The result is that the system exactly recognized the six night sleep.

'Sleeping' is not the only activity that can happen on the sleep mat. A user may take a rest. The proposed algorithm can classify these two activities. Fig. 5(b) illustrates the capability of discrimination. Here, the user lied in the bed during 21:31–22:30 and had a sleep during 22:53–08:03. 'REST_LIE (22:53–23:33)' was converted to 'SLEEP' since the core sleep time for him is from 23:30.

4 Conclusions

In this paper, we have presented a noninvasive ADL monitoring system using FSR array sensors and an optional 3-axis accelerometer. In order for the monitoring system to be noninvasive, the sensor data is transmitted wirelessly and transmitter (especially, body-activity sensor) modules are miniaturized. ADL Inference modules take advantage of rule-based algorithms which do not suffer from difficulties in collecting training data. The features of pressure variation of FSR sensors in various situations have been taken into account in the design of each ADL inferring algorithm. In particular, we have looked into the details in designing the sleep mat (FSR array) sensor. From the experiments, it was verified that using sensor information directly related to each ADL and simple rule-based inferring algorithms are adequate for the purpose of light-weight real-time ADL monitoring system. Particularly, the deployment results of the sleep mat in real home envision the possibilities of the proposed system.

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Efficient Incremental Plan Recognition Method for Cognitive Assistance

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Abstract. In this paper we propose an efficient and incremental plan recognition method for cognitive assistance. We design our unique method based on graph matching and heuristic chaining rules in order to deal with interleaved and sequential activities. The finding of this research work is to be applied to predict abnormal behavior of the users, and optimize assistance for them. We have studied a use case of kitchen environment during lunch time that we will discuss in this paper and targeted Dementia patients. We will present implementation details as well as our evaluation plan.

Keywords: Dementia assistance, plan recognition.

1 Introduction

With the increasing number of aging population and the need to reduce hospital care costs, there is an emerging need from governments worldwide to invest in home care in order to come up with new technological solutions allowing elderly people to stay as long as possible in their homes. People with Dementia, as one category of people suffering from cognitive impairments, represents 5% of all persons above 65 and over 40% of people over 90 years[1][2]. Their care costs are greater than other elder's costs and they require specially trained carers [3]. The home care market attracts many companies and corporations to invest in research and development. One of the main and important reasons that patients with Dementia are moved to the hospital is their inability to perform their Activities of Daily Life (ADLs) and Instrumental Activities of Daily Life (IADLs) independently. To address this issue, we are engaged in work with local nursing homes and hospitals in order to deploy assistive solutions able to help people with Dementia navigate their day independently.

This work is carried out as a part of a research project in collaboration with Alexandra hospital, Singapore to assist people suffering from Dementia. The necessity for continuous 24/7 supervision of patients suffering from this type of disease has given birth to this collaboration with the goal of providing a platform that is capable of monitoring important activities of these patients and assist them to maintain their autonomy.

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2 State of the Art

In our application, we target online activity and plan recognition. Several works address the problem of plan recognition using probabilistic approaches [4][5][6], logic based methods [7][8[9] or learning techniques [10][11][12][13][14]. However, they omit online recognition and base their experimentation on simulated environment. In our work we adopt an application driven approach with online plan recognition. We start our experimentation by exploring the weighted graph theory as described in the next section.

3 Implementation Details of Our Proposed Solution

To address the real needs raised by the specialist and described in the last section, we have prepared a laboratory environment with ambient sensors, that represent a 'smart' kitchen environment of an elderly person living alone. Our system aims to cover and detect cognitive errors as pointed out earlier and to redirect patient to the right activity plan. As a starting point, we assume that doctors and carers plan all activities that must be realized by the patient.

We use graphs as an abstract representation of all activities fixed by doctors and carers. The vertices of a graph represent activities that patient performs in a specific scene, and edges are weighted by the maximum time between two successive activities.

The application receives information sent from different wireless and wired sensors spread out in the scene. The sensors are mostly ambient, however we also consider simple non-intrusive wearable sensors. These sensors gather information that help us to detect all activities performed by the patient. When a patient enters a scene, a graph of activities is created (called the **patient activity graph (PAG)**). Each activity that the patient performs is detected by sensors and sent to the application which verifies the existence of this activity in the **scene graph**:

If the activity doesn't exist in the scene graph, an alarm is triggered to indicate an abnormal activity of the patient.

If the activity exists in the scene graph, then the application verifies the existence of this activity in the PAG, and checks the following steps:

If it is contained in this graph and the time has exceeded the maximum time for the activity, then the application concludes that the patient has entered into a *completion error*, and proposes to him to perform the activity that follows the last activity accepted by the application if it isn't contained in the PAG, otherwise the application informs the patient that the activity plan is achieved.

If the activity isn't contained in the PAG, then the application verifies the existence in the PAG of one of activities that precedes this activity in the scene graph.

If it is the case, then the application adds the activity performed, to the PAG and triggers a timer with the duration separating current activity and activities that follow it to monitor and control *completion error* and *realization error*. When the timer duration has expired, the application requests the patient to perform the activity that follows the activity for which the timer was launched, and restarts the timer. If the activity is performed before the end of the timer duration, then it is stopped.

If no preceding activity is found in the scene graph, the application concludes that the patient has realized a *judgment error*, *sequence error* or *organization error* , he has jumped some steps in his activities plan. The application searches for the last activity performed in this activities plan and requests the patient to perform the appropriate activity that follows it.

If the patient leaves a branch of the graph to a new branch, then a timer is launched with an appropriate duration to control realization errors. When the timer duration has expired, the application requests the patient to perform the appropriate activity that follows the activity that was previously left, and restarts the timer. If he performs this activity before the end of the timer duration, then it is stopped.

To control *Initiation errors*, the application monitors and controls the timing of lunch and medication. When it is time, it requests the patient to perform appropriate activities plan, and launches a timer with a considered duration. The timer is stopped when the patient performs the activity, otherwise, after the timer duration has expired, the application requests the patient to perform the activities plan once more and launches the timer once again.

The description of the implementation details are depicted in the following class diagram.

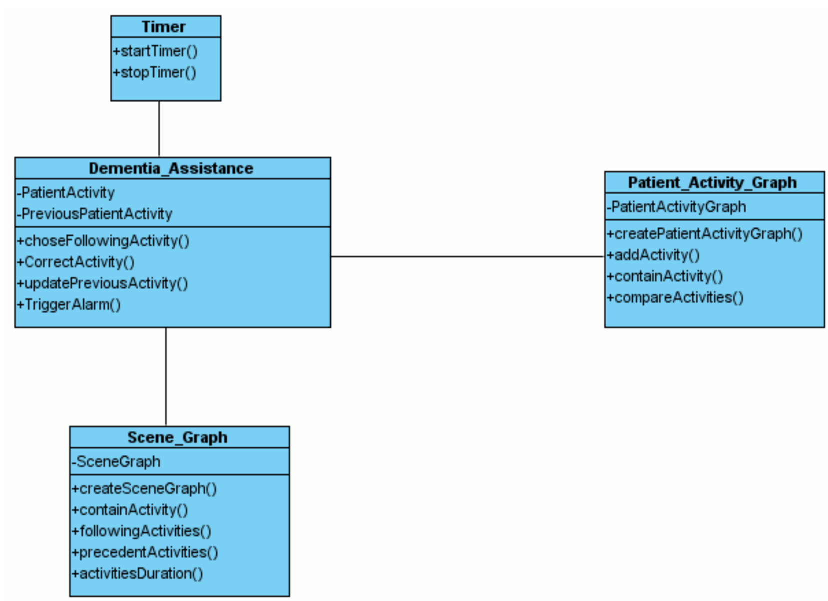

Fig. 1. Activity and Scene graphs main classes

4 Conclusion

In this paper we presented a novel approach based weighted graph matching of recognized activities to the Scene Graph and the Patient Activity Graph.

We motivated our method by a real study and use case scenario provided by medical specialist. We will be able to provide first results of our prototype during the conference main event.

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Home Based Self-management of Chronic Diseases

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Abstract. Research in the area of developing home based self-management systems aim to provide a means whereby a patient suffering from a chronic condition can maintain a better quality of life while achieving their desired life goal. The use of everyday technologies to facilitate the self-management of three chronic conditions has been proposed. In this paper we outline the methodology by which we have acquired the functional requirements for healthcare professionals and patients in relation to three chronic diseases (Stroke, Congestive Heart Failure and Chronic pain), and describe how these requirements have been mapped onto a technological solution.

Keywords: Assistive technologies, self-management, independent living.

1 Introduction

Chronic conditions such as Stroke, Congestive Heart Failure (CHF) and Chronic Pain are considered to be amongst the major causes of disability, dependency and death in many countries [1]. These chronic conditions often result in unemployment, social withdrawal, anxiety of the future and increasing dependence on health and social care services. As a result, a large proportion of health services are consumed treating these conditions [2].

In the United Kingdom, stroke is the largest contributing factor to severe disability [3]. In terms of Chronic Pain, it is estimated that between 7-16 million people in the UK suffer form some form of musculoskeletal pain, which is the second most common reason for absence from work [4]. In 2004 CHF accounted for over 105,842 deaths in the UK, twice the number for Stroke [5].

The aforementioned chronic conditions are thought to be caused, maintained or exacerbated by behavioural factors. Lack of physical activity, alcohol ingestion and poor diet can increase the risk of further complications [6][7]. Behaviours in chronic pain can maintain disability and impede rehabilitation [8]. Given that the behaviour of sufferers has a direct influence on their condition, the recent focus of intervention has been one of behavioural change. At present the current approaches to behavioural change are conducted in a face-to-face manner.

In our work, we aim to develop a technological solution to self-management and behavioural change for sufferers of the three aforementioned chronic conditions.

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2 Background

People who suffer from chronic conditions face a number of challenges to their daily lives. Often they do not understand their condition, and how this requires adjustments to ambitions, aspirations and goals. These adjustments should be geared towards the attainment of a life goal. Life goals vary from patient to patient and from condition to condition, and range from *'attending church'* to '*do a certain amount of exercise'*. Table 1 outlines current methodologies for chronic disease self-management.

Table 1. Self-management Guidelines for Chronic Diseases

Self Management of Chronic Diseases	
Chronic Pain	In young to middle-aged adults, relaxation, exercise, mutation of negative thoughts, education and goal setting have been effective [9].
Congestive Heart Failure	Key components involve patient education, dietary management and medication. Management programs involving education, improve prescribing practices, reduce cost and reduce risk of hospitalization [10].
Stoke	Interventions targeting specific areas such as occupational performance in daily activities, upper limb function, cognition, perception and participation in the community should be tailored to each patient [11].

Chronic pain therapy is largely *accommodative*, whereas Stroke is *restorative*, and CHF is *preventative*. This mix of different intervention models will provide us with the challenge of accommodating different user needs and establishing the impact technology can have to enable self-management

3 Methods

We have adopted a user centered design approach for the elicitation, development and evaluation of a Personalised Self-Management System (PSMS). In this part of the work, the users will be healthcare professionals. This approach is based on three iterations, each iteration consisting of three phases. Phase one will assess the user needs. Phase two will focus on technical development. Phase three will consist of user testing/evaluation. This process is to be repeated for each iteration of the system. Throughout these iterations, functionality will be added, removed or amended based on feedback. The final system will be deployed in 60 users' homes throughout a period of 12 months. These users can take one of two forms:

- **Priority users** suffering from a chronic condition and requiring intervention
- **Support for priority users** are a formal/informal carers or healthcare professionals

Therapeutic content and user requirements were elicitated from a series of focus groups with healthcare professionals from each of the three conditions.

Three focus groups took place at three different locations, each concentrating on one condition and consisting of healthcare professionals for that condition; Stroke (n=6), CHF (n=5) and Pain (n=11). Each session lasted approximately 90 minutes, and was split into two parts. One part consisted of a standard Q&A session with the second part consisting of two design activities, in which participants were asked to write post-it notes describing the feelings about the technologies they used most frequently and how they felt it could improve their work and the self-management process for their patients.

As a result, five key services have been identified that will be developed in the first iteration of the PSMS, including GPS Tracking, Weight Distribution, Self-Reporting, Education and Activity Monitoring.

4 Results

To support the development of the first iterations of the technical prototype, user requirements were evaluated and ranked based on their technical feasibility. The user requirements were subsequently mapped onto a technical solution for the prototype PSMS. The PSMS has four main components; a *Home Hub*, *Mobile Device*, *Sensorised Environment* and *Web Server*, the configuration of which has been based on similar architectures [12].

GPS Tracking, as well as Activity Monitoring was achieved using the GPS and accelerometer hardware on the Mobile Device as shown in Fig 1. A theoretical algorithm was used to analyse accelerometer data [13]. A Nintendo Balance Board was used to measure weight and weight distribution, and a real-time visualization was presented on the Home Hub. Education and Self-Reporting were delivered through interfaces on the Home Hub as shown in Fig 2.

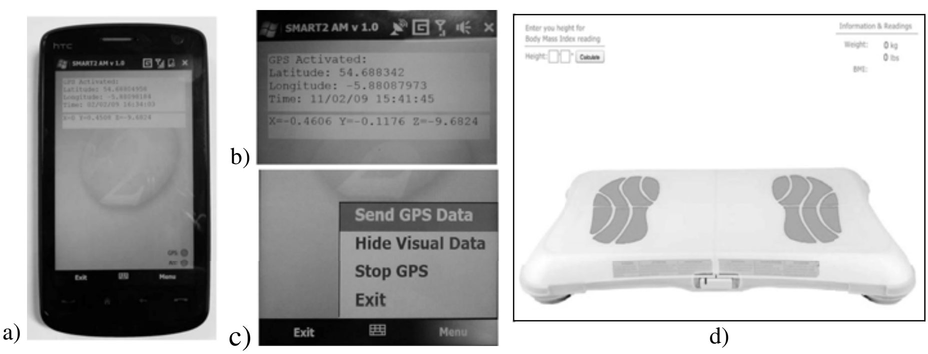

Fig. 1. a & b) Mobile device showing sensor data, stored in a text file on the device c) Menu for GPS system d) Weight distribution interface

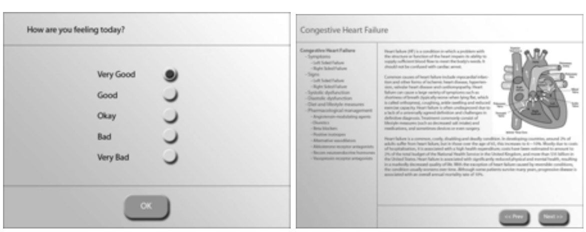

Fig. 2. User interface for Self-Reporting & Educational Content

5 Conclusions

Due to the burden of chronic diseases on the healthcare services, it is clear that the use of technology to promote and maintain self-management of chronic diseases would help decrease this burden. In this paper we have outlined the methodology by which technology could facilitate the self-management of three chronic conditions.

We are currently in the first iteration of the development of a PSMS prototype. The requirements elicited from the focus groups have been mapped onto a technical model, which aim to fulfill the needs of both priority users and their supporters.

Acknowledgements

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SOPRANO – An Ambient Assisted Living System for Supporting Older People at Home

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Abstract. SOPRANO (Service-oriented programmable smart environments for Older Europeans) is a EU-funded project to develop an ambient assisted living (AAL) system to enhance the lives of frail and disabled older people. SOPRANO uses pervasive technologies such as sensors, actuators, smart interfaces, and artificial intelligence to create a more supportive home environment. SOPRANO provides additional safety and security, supporting independent living and social participation and improving quality of life. The paper describes the user-driven approach to research and development within the SOPRANO project and presents results that have emerged from this iterative process. The paper concludes by discussing benefits of the user-driven approach and future plans for system demonstration and large-scale field trials.

Keywords: gerontechnology, smart homes, aging-in-place, independent living.

1 Introduction

We live within a world where we are surrounded with numerous technological devices and innovations that exist to simplify our daily living. Many such designs may be viewed as driven by technology and perhaps novel implementation rather than by the needs of the user. Within the realm of technology and ageing, this has resulted in a focus upon the so-called *problems* facing frail and disabled older people living at home. Such an approach however often misses the point of how technology may or may not be impacting the everyday lives of older people. Without a user-driven research approach that takes seriously these issues, there is a danger that ill-conceived technologies will at best be inappropriate and at worst will reinforce some of the negative ageist assumptions that frame much of society's response to ageing.

Emerging information and communication technologies (ICTs) have considerable potential for enhancing the lives of many older people throughout the world [1]. SOPRANO (Service-oriented programmable smart environments for older Europeans) is a consortium of commercial companies, service providers and research institutes with over 20 partners from in Greece, Germany, UK, Netherlands, Spain, Slovenia, Ireland and Canada [2]. This EU-funded project was set up in June 2008

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with the overall objective of using ICTs to improve the quality of life of older people [3]. The SOPRANO system and its technical components are designed as part of a *socio-technical* system that models both the human and machine domains within a single conceptual framework. This paper will describe the approach that drives the SOPRANO consortium, developments resulting from this iterative process to date, and future directions of the project.

2 The SOPRANO Approach

SOPRANO has been highly innovative both in terms of its approach to the research and development process and in terms of the social and technical work being carried out. A major aim within the project has been to move away from technology-push and problem-focused approaches to user-driven approaches and map out an Ambient Assisted Living (AAL) system that will provide practical benefits for users in their everyday lives. An extensive program of research was carried out involving users at all stages of the R&D process.

3 Developments Resulting from the Iterative Process

Initial requirements included a comprehensive literature review and an inventory of generic situations that threaten older peoples' independence and quality of life. Potential users were involved in order to gather their feedback on the key challenges to independence/quality of life without specific reference on how technology could be used to cope with these challenges. The aim was to identify opportunities for introducing technological support, without being driven by a predefined technical agenda. This qualitative approach involved 14 focus groups (with more than 90 participants) as well as individual interviews. A number of themes emerged from the user research [4]: *Social isolation* (loneliness, depression, boredom, social exclusion and disruption of patterns of daily living); *Safety and Security*: (falls, disorientation, control of household equipment); *Forgetfulness* (appears to be a challenge to independence for many and concerns, for example, taking medication or finding objects in the house); *Keeping healthy and active* (included physical and mental activity, exercise, good nutrition, daily routines and adherence to medications); *Community participation and contribution to local community; Accessing information/keeping up to date* (was a crucial issue as well as finding help and tradesmen to do jobs around the home); *Getting access to shops and services* (problematic for some people); *Quality management of care provision* (is an important issue to ensure that the right amount and right quality of care is delivered in people's homes); *Mobility inside and outside the home* (challenges to personal mobility in terms of walking in the neighbourhood and use of public transport).

The next phase of the SOPRANO project was to use these themes to drive the technological development of an AAL environment that could assist older adults with maintaining independence and thus the ability to age-in-place. Here, the initial user research provided input into a top-level system specification in terms of a set of *use cases* (descriptive models) that explained in a straightforward way the interactions between users and the system itself. It is beyond the scope of this paper to describe each case in detail, however such cases were developed to assist with medication reminding, safety & security, falls detection, home automation, exercise, remembering, social isolation, and entertainment.

To provide one example in further detail the *remembering* use case may be described as follows: the older person wishes to leave the house and opens the door to leave. This is recognised by a door sensor. As a reaction, the SOPRANO system displays a warning on the GUI (e.g. on a touchscreen near the door) that various applicances have been left switched on in the house (e.g. cooker, heater, etc) and that the window is open. The GUI displays options for the user (e.g switch off applicances), and the user responds via the GUI and/or voice command, either to switch off appliances or take no action.

The idea in SOPRANO is that the technology developers should listen to and act on the input from older people and their caregivers. Methods included theatre groups as well as specially designed focus groups applying multimedia demonstrators. The various use cases were transformed into a drama session or animated within a multimedia demonstrator, which were viewed interactively and discussed within small user groups. A total of 72 potential users participated in 27 sessions conducted in the 4 different countries. The multimedia demonstrators and theatre groups successfully revealed specific refinements to all the use cases in relation to functionality, interaction sequence and modality.

The user feedback was crucial in developing an overall architecture for the SOPRANO prototype system. Prototypes have been lab-tested at four sites with more than 50 users between November 2008 and February 2009. This prototype testing focused on refining usability of the different SOPRANO components. Results from this cycle of user involvement helped technical designers to improve the prototype components and overall system.

4 Conclusions and Future Directions

This paper has outlined the method and development of an iterative, user-driven approach to developing the SOPRANO AAL system to support ageing-in-place. While SOPRANO differentiates itself from other R&D projects in its approach, it also is unique in that such a comprehensive system incorporating pervasive technologies such as sensors, actuators, smart interfaces and artificial intelligence has yet to be successfully developed. The paper demonstrates the usefulness of the approach for involving user in all stages of R&D and in generating and evaluating ideas for prototype development. User involvement was beneficial not only in a technical sense (system and component usability), but also in terms of the practical benefits conferred to the user (usefulness) and its appropriateness to their everyday living context (acceptability).

The future direction is the demonstration phase of the project, where the SOPRANO system will be deployed in two ways. First, full-function demonstration facilities will be set up in homes in the UK, Netherlands and Spain. As the technology and services developed within SOPRANO are innovative, it will remain important to get feedback from users at this stage either as input to the design process and/or as evaluation on the functionality of the total SOPRANO system. The full function trials will support all the use cases mentioned above. However, some of the use cases may be deployed in a slightly limited manner. Second, large-scale field trials of a more limited version of the SOPRANO system are also planned to evaluate its impact in real-life situations with 600 users across Europe. The information from the demonstration phase will provide critical information on the practical and commercial deployment of the SOPRANO AAL system. This is interesting given that the actual and potential benefits of ICT-based solutions, clinical, social, commercial, or otherwise have yet to be demonstrated [5]. Sixsmith points to the very limited nature of any evidence to support large-scale implementation [6]. Therefore the upcoming SOPRANO field trials should contribute to providing such verification.

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An Agent-Based Healthcare Support System in Ubiquitous Computing Environments

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Abstract. This paper presents an advanced healthcare support system in ubiquitous computing environment. By utilizing knowledge about healthcare and various information including vital sign, physical location, and video data of a user under observation from real space, the system provides useful information regarding health condition effectively and in user-oriented manner. In this paper, we describe a user-oriented healthcare support system focusing on design and implementation of the system with multi-agent technology.

1 Introduction

Daily life support system is wide-spreading, and it is challenging as well. There is a steady increase of number of people suffering from various life-style related diseases such as obesity, hypertension, diabetes and hyperlipidemia. To prevent these diseases, maintaining a healthy life-style has become an important issue and a great concern for the society. Information technologies are expected to provide practical solutions to this issue. However, these existing systems are designed by using some specific vital sensors and electronic devices. Therefore, these systems are limited in ability of healthcare support. In order to provide useful information for healthcare of an object person, not only to him/herself but also to related people of the person, the system should acquire variety of information, knowledge, data, etc. from real space and store/manage them in a methodical manner.

This paper describes a new dimension of design and construction of large-scale systems with multi-agent technology that can cope with many kinds and amount of information on unstable processing environment of ubiquitous computing.

2 Related Works and Problems

Some research groups developed support systems which recognize health condition of a user by monitoring user's vital signs using compact sensors, hand-held

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PCs, and wireless network in ubiquitous computing environment [1,2,3]. Some existing system infer user's behavior, activity, and emergency situation according to the vital signs and location information of the user's by using wearable sensors. We point out the technical problems in existing system as follows.

•Effective acquisition of amount of information related to healthcare
There are studies that determine the health condition based on vital sign by specific sensing devices. But the information has limitations for obtaining an accurate estimation of the health condition. It would be possible to perceive the health condition of object person with greater accuracy using physical location, environmental information, and video information, as well as the vital sign. However, it is difficult to acquire all the information because of the limitation of computational resources and network resources in the ubiquitous computing environment. Consequently, we need to consider the effective way of information acquisition.

•Service provision based on various kinds of information of real space
After acquisition of various kinds of information from real space, effective information and service provisioning using the information can be challenging. The data and information including vital sign, location information, environmental information, multimedia data, specialized knowledge, etc. contain significant diverse aspects in both quantitatively and qualitatively. Therefore, it is essential that the mechanism should be able to actively provide the required data and information to a particular user who really needs, in appropriate place, with suitable format, only when the user needs, by effective management.

3 Concept of User-Oriented Healthcare Support System

Our system supports an object person and community members who are related to the object person such as family member, sports gym instructor, and doctor to circulate healthcare related information and knowledge effectively. The system collects information on the object person such as profiles, preferences, history of exercise, medical records, and human relation from the community members. The system actively observes the current status of the object person and his/her surrounding environment such as physical location, room temperature, body warmth, HR, and BP by using various types of sensors.

Meanwhile, the system accesses the Web site and databases (DBs) via the network to fetch useful information on healthcare. The information, data, and knowledge are accumulated in the system in adequate forms. If needed, they are used to analyze the situation of the object person in detail. The information is sometimes provided to the person and the community members by proper timing and forms, considering privacy concerns and resource limitations of the devices.

Consider the situation where some vital data or location information is acquired by a sensor device, transmitted via the network and stored in a DB. Here, each agent individually resides in various devices, and monitors and controls corresponding hardware. Also the DB is made to work as agent. Quality and frequency of the acquired data should be controlled depending on network status, operational condition of the sensor device, and the load of the DB. The proposed system can effectively control the data flows by cooperating among sensor agent, DB agent, and network agent.

The accumulated information is basically in the form of raw data. It should be converted into more user-friendly forms such as tables and graphs. Some data can be used to analyze the situation of the object person to create knowledge or advice with high-level expression. For example, when the object person is in critical condition, the sensor agent that gets the vital data of the person would try to acquire more detailed information in shorter time intervals based on the rule-base system.

4 Experiments

For our healthcare system, we are developing mainly part of the real-time multimedia supervisory function that delivers live video streaming. We used DASH [4] for implementation of agents. Our system displays a live video with suitable quality on one of the displays considering the requirement for the watching over, the status of devices such as the camera and the PC, and person's location. In this paper, we present the privacy protection function and visualization function.

As for privacy protection function, we are trying to give the function to our system by controlling the level of quality as shown in Fig. 1. This function adjusts the parameters related the video quality of JMF such as frame rate and bit rate in accordance with the video format (Motion-JPEG and H.263). In fact, JMF-send agent and JMF-rec agent cooperate to adjust the parameters and the format depending on the situation of network resource and human relationship. We can only judge the person's movement without showing his/her face clearly. This function can easily protect and control the privacy as needed.

Additionally, we are developing the visualization function of the watched person's situation. Fig. 2 shows an example of the coordination with DB agent which manages watched person's location information. The DB agent can cooperate with various agents. The graph agent displays his tag's height. It is used to judge the state of emergency such as the falling down etc. The map agent displays the watched person's position in his house. The blue point means he

(a) H.263 (b) Motion-JPEG

Fig. 1. Privacy protection function in case of H.263 (a) and Motion-JPEG (b)

Fig. 2. Visualization function of the watched person's situation

is in normal situation and his position (Fig. 2(a)). The map agent alerts the watching person to the watched person's situation in emergency by the flashing red point (Fig. 2(b)).

5 Conclusion

We presented a concept of user-oriented advanced healthcare support system based on multi-agent technology in ubiquitous computing environment. The system provides useful information regarding health condition effectively and in user-oriented manner by utilizing knowledge about healthcare and various kinds of information obtained from real space. We designed and implemented an initial prototype system, and demonstrated its two functions.

Acknowledgement

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A Ubiquitous Computing Environment to Support the Mobility of Users with Special Needs

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Abstract. This paper presents a ubiquitous computing platform over which services are hosted and operated for users in a transparent fashion. To that end, the platform draws on mobile agents that act as surrogates to their user, following him within his environment by migrating to the system's nearest access point and operating the latter's services for him in a personalized and automated way. The goal of this system is to better support the mobility of people with special needs, by providing them with assistive services that require minimal effort and investment from their part.

Keywords: Ubiquitous computing, assistive technologies, mobile agents.

1 Introduction

One of the greatest values of ubiquitous computing lies in the support it can provide to people with special needs [1], who must often exert added efforts to operate within environments that are barely accommodated to them. However, developing a system suitable for assisting these individuals while on the move outside of their home presents several challenges. Among them is implementing an intuitive user interface that should ideally be accessible in most - if not all - times and locations. A prevalent approach has been to involve the user into carrying his own interface to the system, in the form of a wireless portable device [2, 3]. While this approach makes good use of widely disseminated technologies such as PDAs and smart phones, it does come with some shortcomings at the time being. First, the input/output interfaces of typical portable devices are restrictive in many ways. Their densely packed touchpad, as well as their undersized display screen, make them unsuitable for use by many people with disabilities. Moreover, their expensiveness deters most people from owning more than one. Thus, if it is trust upon by the user or the assistive system to store sensitive information, it essentially becomes a single point of failure and a privacy Achilles heel, in the event that it breaks, is lost by its owner or stolen from him.

To address these issues, a device-agnostic assistive environment was developed with the purpose of better supporting the mobility of people with special needs. This paper presents the rationale behind this system, as well as an original application.

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2 Approach

The assistive environment developed within the framework of this project is based on a distributed system composed of four types of elements : the Access Point, the User Agent, the Agent Repository, and the User Portable Device.

- Access Point (AP): physical entity that runs a software platform for the purpose of hosting and managing the system's services and active UAs.
- User Agent (UA): a software agent that acts as a user surrogate, selecting, customizing and operating services for him based on his needs and limitations. UAs also have the ability to migrate from one AP to another in order to follow their owner.
- Agent Repository (AR): physical entity in charge of storing inactive UAs within an agent database and deploying them over to the appropriate AP, upon request.
- User Portable Device (UPD): a wireless device that is carried by a user as he goes about his daily activities. It acts as his unique identifier within the system and can also serve as a remote control for customizing or overriding his UA's behaviour, provided it is equipped with adequate input/output interfaces.

Fig. 1 illustrates the relationships between these elements and their underlying components as they are mobilized, following a user's arrival within range of an AP.

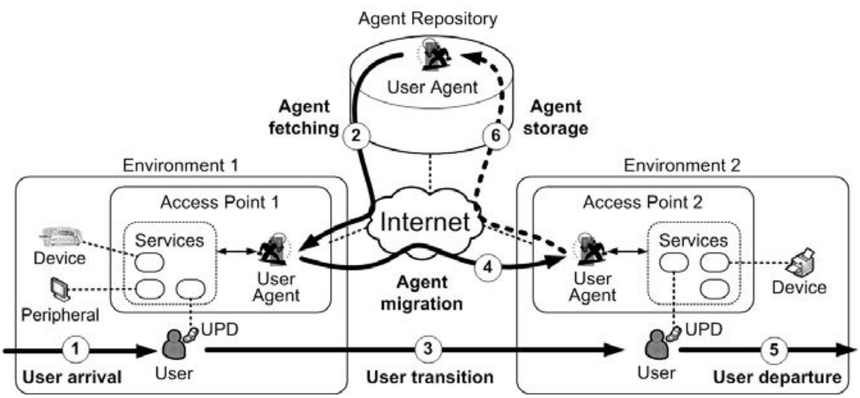

Fig. 1. Architecture of the ubiquitous computing platform

With the proposed system, users typically go about their daily activities and errands, bringing with them a UPD. As one of these users comes within range of an AP, his UPD automatically connects to it over the air, which triggers a requests to the AR for fetching the UA that represents this user. Granting this request, the AR then retrieves the UA from within its agent database and activates it. Following this step, the UA migrates to the requesting AP where it can begin its work. First, it asks the AP for a list of available services, in light of its owner's access rights. Then, the UA proceeds to select services for interacting with the user it represents, either through the latter's UPD (provided it is equipped with adequate input/output interfaces) or through the environment's peripherals (if available) connected to the AP and managed by it. After this, the UA selects, configures and operates the AP's assistive services for its owner based on its preferences and limitations, mobilizing the aforementioned devices in order to communicate relevant information to him. It is worth mentioning that these devices can also be operated by the user to manually control the services in order to override the UA's decisions. In any case, the user will eventually go away from the AP, thus leaving his UA idle. As this user passes on, he might shortly return, in which case the UA will be able to resume its functions, or reach another AP, to which the UA will migrate in order to follow its user and carry on its work. At last, as the user continues his way, he will eventually leave the coverage of the assistive system. His UA, updated with new preferences from customizing services for its owner, will then return to the AR for storage until its next use.

3 Implementation

In order to illustrate the aforementioned notions, a proof of concept system was implemented within the framework of this project. This prototype is made of one AR networked with two APs, to which two developed UPDs are able to connect. Below, more implementation details are given for each of these components.

The AR is embodied as a Java application running on a typical computer connected to the internet. It manages an agent repository in the form of a MySQL database, and a JADE-based [4] multi-agent system for hosting UAs in their transitory state.

The APs are also built from typical computers, connected to the internet and fitted with wireless communication interfaces (Wi-Fi and ZigBee [5]) for supporting UPD connections. On the software side, APs are composed of a Java-based, component-oriented computing environment called the OSGi service platform [6], on top of which the services run and are managed. One of those services operate an instance of the aforementioned JADE runtime for hosting an agent container for the visiting UAs.

Two UPDs of differing capabilities were finally implemented to assess of the system's scalability. The first device was built from a simple battery-powered ZigBee module, while the second was embodied by a laptop that communicates via Wi-Fi.

4 Application: An Assistive System for Public Places

A software platform ultimately demonstrates its viability if it proves efficient a tool for solving common problems or devising novel and useful applications. Presented below is a sample application which would make good use of the developed platform, in the form of an assistive system for supporting the mobility of people with special needs inside airport premises.

One challenge mobility impaired users face when visiting an airport is locating and then reaching its areas of interest (check-in counters, terminals, commercial services, etc.). Making use of the developed system, airport authorities could judiciously install several APs at strategic locations, in the form of self-service kiosks. Equipped with a touchscreen and miscellaneous peripherals (keypad, microphone, speakers, etc.), these devices would not only act as conventional kiosks, but as adaptive ones, detecting a user's arrival by the signal emitted from his UPD (such as a smart phone), and customizing themselves to his liking on the fly, thanks to his UA. For instance, the latter could select the appropriate language for displaying information, increase the screen's font size and contrast to suit the needs of a user with moderate visual impairments, or activate text-to-speech and voice recognition for interacting with a blind user. Through the UA's intervention, the assistive system could even make use of the person's own UPD as part of its Human Computer Interface. Users with a PDA could opt to interact with the kiosk through this device instead of its touchscreen. As a wheelchair user with a severe physical impairment might not enjoy a sufficient range of motion to access a touchscreen, he could rely on his own keyboard, conveniently installed on his wheelchair's arm, to operate the kiosk's services.

Finally, with the interface properly configured, the UA could then proceed to select, configure and operate services for its user. Among the variety of possible offerings, services could range from simple notifications (flight status, time before departure, flight and gate number) to interactive maps showing the path to adapted facilities (telephones, restrooms, check-in counters) and to the departure gate.

5 Conclusion

This paper presented a ubiquitous computing platform over which personalized and location-based services can be hosted and operated for users with special needs, in order to better support their mobility when outside of their home.

Various useful applications have been envisioned that would make good use of the proposed system, such as navigation assistance systems, some of which are currently under development. Additionally, their investigation have helped substantiated several of the chosen method's benefits. For instance, the platform offers much scalability in terms of the wireless portable computing devices it supports for interactions: as the computation is performed on the Access Point instead of the device itself, the latter can be as simplistic and cheap as possible, down to an RFID-tag. It can also be entirely custom-made, in order to support the specific needs of its user. Finally, the portable device does not become a single point of failure and can be replaced or used alternately with another without requiring synchronization.

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Evaluation Metrics for eHealth Services and Applications within Smart Houses Context

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Abstract. eHealth services is a continuously growing sector, driving the need for advances in both the network characteristics and infrastructure, as well as in the available mobile devices used. The same need requires the development of quality software applications to facilitate and service eHealth activities. On these grounds, this paper proposes a novel evaluation methodology that takes into consideration the peculiarities of sensor/actuator related services. It further focuses on aspects of software quality for eHealth services and applications, and identifies a set of quality characteristics and attributes to take into consideration. These quality characteristics are integrated into our proposed evaluation methodology during the analysis and engineering phases, which is a revised version of the spiral software process used in web engineering. The efficacy of the proposed approach in a real scenario is discussed.

1 Introduction

eHealth services and applications are becoming more and more adopted in today's modern mobile computing society. Some factors that contributed to this end are amongst others the impressive growth of wireless mobile and sensor networks and actuators. The integration of the latter technologies into residences has led to the construction of Smart Houses (SHs). SHs are the evolutionary technological step of home in current society. Currently, many researchers have studied various aspects of Smart Houses [9,10,11]. A SH relies on real-world sensory equipment data, which are collected from smart integrated sensors/actuators that reside in heterogeneous distributed environments. Based on this input, the smart integration of sensors enables us to recognize the user interaction, sensing the situation and observe the context of the interaction and providing data inputs that can be analyzed and utilized for related eHealth services' decision making.

The main objective of this paper is to suggest a new approach for promoting quality in eHealth services and applications in smart houses, by enhancing existing evaluation methodologies for their assessment. To accomplish this, we propose a set of quality characteristics along with their corresponding metrics, that that take into account the peculiarities of developing eHealth services that employ sensor/actuator technologies. In order to validate our approach we evaluate the MPower project's [2] middleware platform using our evaluation methodology.

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2 Extending Evaluation Metrics for Smart Houses

Nowadays, a "Smart House" is considered to be a blending of wired and wireless computational technologies including sensors, actuators and processing units that cooperate with the aim to improve the quality of life of the user. Although current evaluation methodologies [12] seem to comprehensively approach the issue of services assessment, they are still lacking of focus regarding particular constraints and/or advanced technologies and tools incorporated nowadays in SHs, such as the use of sensors and actuators.

In this particular work, we are specifically interested in sensor and actuator technologies that support the creation of a smart house environment. In general there are two broad categories of classification regarding sensor devices: (a) *Smart House Sensors* (usually used for increasing the quality of life of the user), and (b) *Commercial Sensors* (providing mostly customized solutions to specific areas). To accommodate this additional functionality provided by sensors and actuators many new reference architecture models have been proposed [6,7,8], with Service Oriented Architecture (SOA) [5] being the most dominant.

However, little research effort has been devoted to the design and development activities of such sensor/actuator powered eHealth services and applications with the research effort to be mainly emphasized on mobile applications. Indicatively, a software quality model for mobile applications is presented in [1] denoting the general characteristics, sub characteristics, along with attributes and their metrics.

Nevertheless, as we can easily observe, the existing criteria are lacking any support for the sensor and smart house integration. In this regards, sufficient extension quality metrics criteria for eHealth services and applications within sensor smart homes context could include: (a) Sensor monitoring, (b) ease of management, (c) interoperability, (d) diversity of usage, (e) robust operations, and (f) flexibility. The abovementioned enhancements will be used as the base for the proposed evaluation methodology.

3 Proposed Evaluation Methodology and Metrics: The Case of MPower

Our proposed evaluation methodology (see Figure 1) starts by specifying the goals for this evaluation which enables us immediately after to define the quality metrics that we want to involve in the process. Although many quality metrics can be incorporated in the evaluation of software services, not all will prove highly useful at the end. All of the quality metrics introduced in the previous step are rated based on the importance and some of them are omitted due to low importance score. This results in the formation of the final quality metrics list that will be utilized in the process.

Subsequently, we identify the stakeholders that will be used to evaluate system based on the quality metrics produced in the previous step. Based on the stakeholders' expertise as well as other parameters (e.g., location diversity, network access) we develop an examination method. During the development of the examination method various information collection methods will be analyzed and some will be selected to carry out the evaluation. The final step is the presentation of the evaluation results.

Fig. 1. Evaluation Methodology

Henceforth, the three new components introduced namely, *Define Quality Metrics*, *Rate Importance of Metrics*, and *Finalize Quality Metrics* (clearly note in fig. 1). The remaining four elements are usually found in such evaluation methodologies [3]. An optimized series of quality metrics that is utilized in the evaluation process has been selected and categorized according to specific aspects of the MPower middleware platform. Those are: Usability, Flexibility, Easiness, Performance (time), Performance (work), Interoperability, Robustness, Security, Multilingualism, Documentation, User satisfaction and Error Handling. These metrics ranked as most important due to eHealth context, peculiarity and constrains arising (e.g. Confidentiality, Security, Availability, Ease of Information Sharing, Expandability and Awareness).

It has to be noted that in the MPower project case, we have ranked the quality metrics with respect to the usability aspect of the platform, as if not satisfied may render the platform useless and the inability of been adopted.

4 Experimental Method and Results

Given the experimental setting constraints (users located in different facilities scattered across Europe) the user sample was around 20 users. We've ruled out information retrieval methods that require human interaction like Interview, Focus Groups, Observations and Case Studies and opted for online questionnaires. Specifically, we have tailored an online 100 items questionnaire method [4] and invited our user group to answer a series of questions organized in categories. Each question had to be answered in rating scale form which enabled us to extract and aggregate the evaluation results in a trouble free manner.

The results of our case study were really promising for the future of our work, showing that we have successfully managed to apply the proposed evaluation methodology in order to assess the MPower middleware platform. We list below the most significant gains of our evaluation:

Firstly, our evaluation methodology succeeded in providing continuous feedback to the developers of the MPower middleware platform through various phases of the project's lifecycle. This resulted in creating more usable and robust eHealth services. Secondly, utilizing our methodology made it easier for developers to methodically customize services to the specific needs of selected and new user groups. Thirdly, it lowered the development costs that leaded to an increase in the number of services developed and enhanced functionality of provided services.

5 Conclusions

Current evaluation methodologies of Smart House eHealth services seem that do not include all these components that can comprehensively assess them since they are lacking elements referring to latest advancements such as sensors and actuators. Therefore, in this paper we have proposed an evaluation methodology that takes into account the unique characteristics of sensor/actuator powered eHealth services. In order to prove that our methodology is successful, we have utilized it to assess the MPower middleware platform. We have observed that applying our methodology led to the production of highly usable and robust eHealth services while reducing the time, cost and complexity required to develop such services.

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Design and Implementation of Mobile Self-care System Using Voice and Facial Images

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Abstract. Individual effort toward wellness is the most important factor to prevent and manage health risks. Though physiological sensing devices and self-care applications support that, sensing devices of most existing mobile healthcare systems are very expensive and the service only provides basic notification about a patient's condition. In this paper we propose a mobile self-care system using voice and facial images. The system consists of a health monitoring module and a symptom checking module. In the system emotion, age and gender information are acquired automatically by using distributed computing-based server-side multimodal emotion, age, and gender recognition system using voice and facial images. The user is then able to use their own voice and face effectively for wellness self-management.

Keywords: self-care, mobile healthcare, self-monitoring, self-diagnosis.

1 Introduction

Individual effort toward wellness is the most important factor to prevent and manage health risks. Health risks arise from a mixture of genetic, lifestyle, and environmental factors. Personal factors such as mindset and behavior are the most prominent domains of influence over health, and only they can be controlled. Our daily choices about what to eat and how we plan activities have been closely associated with our health. Therefore, the effort to detect disease and behavior changes early is essential to improve personal health before abnormal conditions can develop into serious health problems [1]. Physiological sensing devices and self-care applications give support to daily health monitoring. Research has concentrated on health monitoring using sensor technology, wireless communications, and information technology. For example, BioPebble [2] is a stone-type mobile physiological sensing device which provides a comfortable, stable interface. And it analyzes physiological signals and gives feedback according to individual users.

However, current mobile healthcare research only focuses on monitoring users with expensive sensing devices to determine a simple good or bad health diagnosis without any other feedback. This research also only focuses on patients, especially chronic patients, with hypertension or obesity. Also, most current self-care applications are not accessible because they are usually utilized through web pages or printed material. Though the Wellness Diary [1] was developed to manage personal wellness by

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observing actions, thoughts, emotional reactions and other variables, manual entry of the data didn't allow a wide enough range of feelings during real experimentation. Recognizing a changing emotional status is important to understand an individual's mental state at any given time. To resolve the problems, we propose a mobile self-care system using voice and facial images. In Section 2, we describe the entire system and section 3 shows a real-world scenario of the proposed system. The last section contains concluding remarks and future directions.

2 Mobile Self-care System Using Voice and Facial Images

Fig. 1 shows a diagram of the proposed mobile self-care system. The system consists of three parts: a mobile device, a server, and a communications link. The mobile device and server are connected by a communications link, and the link is composed of a wireless network and LAN for each connection. The proposed system consists of three modules: 1) a user checking module; 2) a health monitoring module; 3) a symptom checking module. At first, the user checking module needs two pieces of information (age and gender) before it can begin its process. Though those are basic pieces of information, they are important because the symptom flow chart is divided by

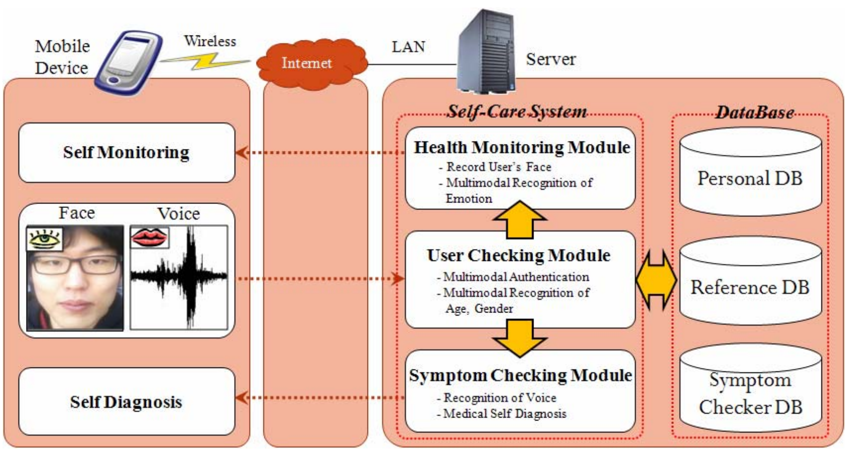


Fig. 1. Entire Mobile Self-care System

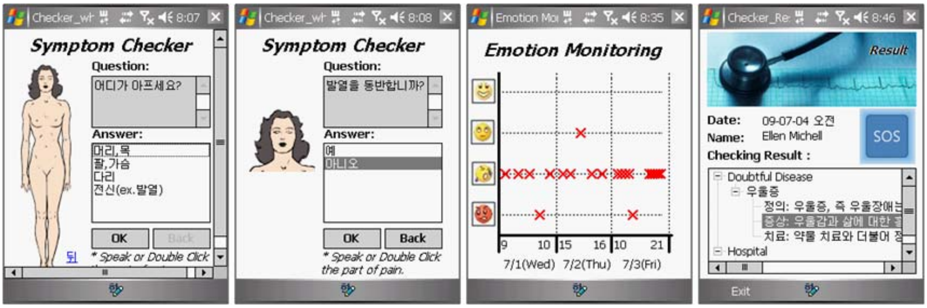
gender and by age [3]. For registered users, we proposed a multimodal authentication approach using tooth images and voice as biometric traits [4]. In the case of anonymous users, the gender and age are determined by a multimodal recognition system using the anonymous user's voice and facial images. Then, we developed a system to recognize age and gender based on the Gaussian Mixture Model (GMM) using an FFT spectral entropy-based feature to decide between male and female and four age groups: child, young adult, adult, and elderly. However, if gender and age is not recognized, users should enter their basic information manually.

The health monitoring module has two functions. One is recording a user's facial images and displaying them for self-monitoring. The face can act as a map identifying the health status of your body. For example, face color, skin condition, wrinkles or cracking and the discoloration of the lips or the mouth can all help to identify health problems. Additionally, parts of the face correlate with organs in the body. This can be used as one indicator of your overall well-being. For that, users need to enter photos of themselves with the built-in camera on their mobile device. The server receives those photos and detects the facial region using the AdaBoost algorithm based on Haar-like features [4]. The analyzed image is then validated and saved in a personal database. The second function is a multimodal emotion recognizer which uses voice and facial images to create a model for anger, sadness, happiness, and neutrality. For recognizing emotions we use a pattern recognition algorithm which is run as a user inputs voice commands to use the self-diagnosis and transmits their facial images for self-monitoring. Recognized emotional information is also saved on the personal database for checking the user's emotional changes over time.

The symptom checking module is largely divided into two sections. Those sections are a disease ontology and symptom flow chart. The disease ontology is the medical domain ontology that includes knowledge about every part of the human body and the diseases associated with it. The concepts are defined and set into categories based on human organ systems. Instance names are set by disease names and linked to concepts related to the specific body parts or the whole body. We refer to [3] for properties with three main pieces - definition, symptoms, and treatment - of information about the disease. Disease instances of ontology are connected with symptom flow chart results. The symptom flow chart is used to check a user's condition through symptoms. Users can identify a certain disease and take the proper action, either prevention or going to a hospital.

3 A Real-World Scenario Using Mobile Self-care System

Miss Ellen (age: 36) is a team leader of a global company as an investment analyst. And she is a mobile self-care system user who monitors herself frequently. One morning she had a terrible headache at work. So she checked her symptoms using the symptom checking module (Fig. 2. (A)). She selected the headache among the main head-related symptoms. Then she answered yes or no to the questions about her symptoms (B). The suspected disease was a tension headache and she felt sure of it because she noticed her symptoms matched with the symptom information provided by the system. She judged that it was not serious enough to go to the hospital and tried to think easy. However, the headache didn't leave her and she additionally suffered from diarrhea. She again checked her symptoms using the symptom checking module and she decided to go to the hospital following the diagnosis. At the hospital an intern diagnosed her with irritable bowel syndrome and recommended making changes to her diet and lifestyle and getting regular exercise to manage stress. She tried to keep the physician's advice but she was feeling lazy and did not do anything. At that time, she monitored the changing of her emotional status using the health monitoring module (C) and noticed her emotion was consistently sad recently. So she checked her risk for depression and was alerted that she may be at risk for major depression (D). She met a psychiatrist and recovered under the treatment of the expert.



(A) (B) (C) (D)

Fig. 2. Snapshots of a Scenario (A) Symptom Checking Module (B) Selection Process (C) Emotion Monitoring (D) Diagnosis

4 Conclusion

We applied multimodal emotion, age and gender recognition technologies using voice and facial images to the proposed system. The intuitive interface could be especially useful to elderly people. Our system also supports health consumers preventing and managing health risks by self-monitoring and self-diagnosis. Through the scenario, we confirmed users can get early disease detection by their symptoms and informed choice with health and disease information. The user is then able to use his or her own face and voice effectively for wellness self-management. Our future investigations will conduct long-term user studies for usability, usage and acceptance. We will also raise the recognition rates of emotion, age, and gender for better practical use.

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Towards a Service Oriented Architecture (SOA) for Tele-Rehabilitation*

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Abstract. In this paper we propose a new model for tele-rehabilitation based on the Service Oriented Architecture (SOA) approach. SOA can be defined as a group of services that communicate with each other to provide a design framework with a view to realizing rapid and low-cost system development and to improving total system-quality. This approach has proved its efficiency in domains like e-Business and e-Learning. Our approach is so to develop an integrated information system for remote rehabilitations based on a Service Oriented Architecture (SOA).

Keywords: tele-rehabilitation, Service Oriented Architecture, Web Services.

1 Introduction

The major characteristic of tele-rehabilitation is to provide assistance for handicapped, via the Internet, anytime and anywhere. Tele-rehabilitation implementations have been developed, providing different remote capabilities for patients. In some implementations, therapists prescribe a set of exercises via the web then controls the patient's performance but without the possibility to perform real-time interaction or training. Other implementations provide audio/visual communication between the patient and the therapist. There are also implementations providing a real time interaction between the patient and the remote rehabilitation system using specific interfaces. These proposals have proved their efficiency in the domain of tele-rehabilitation but a more robust and portable architecture framework is needed in today's heterogeneous computing environment. For this reason this paper proposes an approach based on a Service Oriented Architecture for tele-rehabilitation.

This paper is organized as follows: section 2 presents existing platforms for tele-rehabilitation and stresses on their limitations. An overview of the Service Oriented Architecture, its integration with the Web Services and its applications is outlined in section 3 while section 4 describes our proposed model using SOA for tele-rehabilitation. A conclusion is provided in section 5.

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2 Tele-Rehabilitation

Tele-rehabilitation is the process of delivering rehabilitation services over a telecommunication network. Usually tele-rehabilitation systems provide an interactive communication using webcams, tele-videoconferencing, videophones or other.

Different platforms have been proposed to provide tele- rehabilitation services such as PLEIA [1], Unitherapy [2], Arm-Training with TWREX [3], PC-based Tele-rehabilitation system with force feedback [4] and Networking Telemedicine in Portable Rehabilitation Robot Monitor System [5].

References [1 – 5] have been studied and compared, the following limitations were oulined: (1) In all of the existing platforms the integration of new categories of peripherals is either impossible or very complex. A universal access model is so needed. (2) The architectures of the existing platforms are centralized. A distributed architecture is so required. (3) It is difficult to integrate or re-use existing solution. A more flexible architecture is needed.

3 Service-Oriented Architecture

A service-oriented architecture (SOA) is essentially a set of re-usable building blocks or modules called "services" that can be consumed by clients in different applications or business processes. Applications based on the SOA approach are using different pre-defined common or standard services (e.g. bank transactions, hotel reservation, airline ticket order,…) linked and sequenced together in order to meet a business system requirement.

The ability of the SOA approach to adapt quickly to environment's dynamic, enables it to gain ground as a mechanism for defining services in different domains such as Business and e-learning. Service oriented architecture concept has proved its efficiency in e-learning. With some particular considerations, requirements for the design of an SOA tele-rehabilitation platform are similar to those mentioned in the frameworks above. This is why our suggested model described in the next section is inspired from SOA e-learning.

4 The Proposed SOA Model for Tele-Rehabilitation

Based on the SOA approach, the existing tele-rehabilitation solutions and SOA e-learning models, we proposed our SOA tele-rehabilitation model. The proposed model outlines three entities: the entities that interact with the system, the data repository and the integrated services. These entities are presented in the following sections.

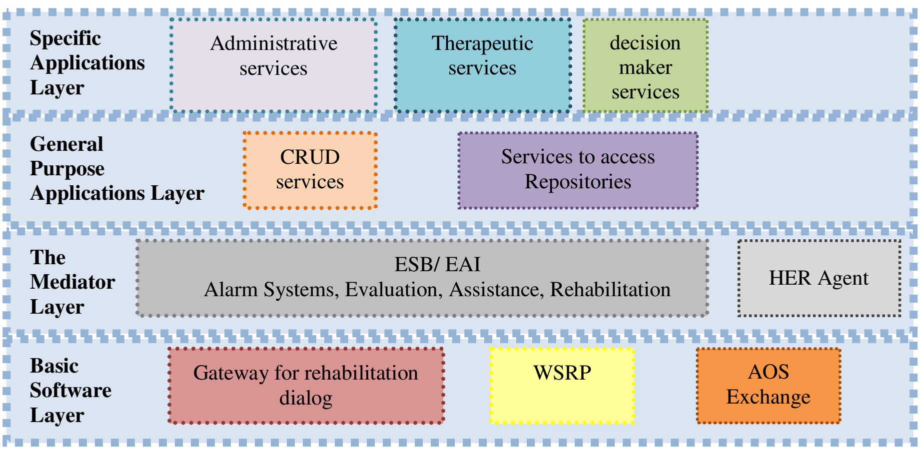
4.1 Entities That Interact with the System

Entities that interact with the system could be humans or system components. Concerning humans, the following categories are identified: (1) the patient who uses a web interface or some medical peripherals to access the system in the objective of getting a medical assistance, evaluation or therapy, (2) the system users other than patients are therapists, clinicians, nurses and family members. These users are involved in defining and conceiving guidelines for helping patients while using the tele-rehabilitation system, (3) the system administrator is in charge of integrating existing services in the system, maintaining, controlling and updating the system.

Systems that interact with the platform are classified in three categories: (1) the monitoring system that receives monitoring messages and executes the appropriate monitoring action using the communication layer via the monitoring agent, (2) the system alarm that receives alarm messages and redirect them to the adequate person using the communication layer via the alarms distribution agent, (3) the Electronic Healthcare Record (EHR) responsible on translating the patient's information for the XDS Repository/Registry using the HL7 standard.

4.2 Data Repository

The following data repositories are considered in our model: (1) the guideline repository that stores guidelines defined in the GLIF (Guideline Interchange Format) format, (2) the central repository, using a relational database and considered as the central reference that enables information sharing between the system components, (3) the Universal Description Discovery and Integration (UDDI) standard for listing web services on the Internet, (4) the XDS Registry/Repository that stores the patients' Electronic Healthcare Record.



4.3 Integrated Services or Applications

At this level we identified four architectural layers as shown above:

In the specific applications layer we propose to define three categories of services: (1) the administrative services related to patients, users and devices, (2) the therapeutic services for deploying guidelines and assigning them to patients and (3) the decision maker services related to updating guidelines according to the evaluations' results.

These specific applications are using services from the general applications layer to access the repositories and the CRUD (Create, Read, Update, Delete) services. The mediation software layer is using the two technologies ESB and EAI. ESB is based on standards as web services, MOM (middleware orientés messages), JMS (Java Message Service) and JCA (Java Connector Architecture). This layer integrates ESB and EAI to access the alarm system, the EHR agent along with the services for evaluation, assistance and rehabilitation exercises.

Just a general description of the model is presented in this paper, while a detailed representation using UML diagrams and defining every function and sub-function in the system is proposed in [6].

5 Conclusion

In this paper a new approach using SOA for tele-rehabilitation systems is proposed. The model described in section 4 is inspired from the requirements and limitations of the existing tele-rehabilitation platforms and the proposed standards for using SOA in the e-Learning domain. Further work will focus on models implementation and on the integration of an "ontology agent" responsible on adopting ontology in the domain of tele-rehabilitation.

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IP Multimedia Subsystem Technology for Ambient Assisted Living

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Abstract. Ageing population is increasing compared to general population. Related to this, a group of social-healthcare services, known as Ambient Assisted Living (AAL) services, are appearing to promote health and wellness in elderly people. IP Multimedia Subsystem (IMS) technology can help to face this challenge providing networks convergence and a fast and solid service implementation. IMS offers a group of common services which can be reused in different applications, and enable the running of the same application over any device, anywhere and anytime. We propose a conceptual implementation of AAL services through generic IMS services (service enablers), We also show the benefits they can offer in order to support a healthy and independent life on elderly people.

Keywords: Ambient Assisted Living, IMS, ageing people, network-service convergence, enablers, multimedia services.

1 Introduction

Nowadays, the world population is undergoing a demographic change due to a progressive ageing [3]. Moreover, technical and medical advances are turning morbid diseases into chronic diseases; promoting the inclusion of disabled people in the society and improving their personal autonomy. All these factors are prompting a need for assistance services, nowadays unfeasible due to the current clinical assistance model. This model focuses on acute pathologies instead of prevention, and is supported by patient's relatives whose familiar structure is changing.

Information and Communication Technologies (ICT) are taking a major part of social and healthcare services for elderly people evolution. They make possible to move some care services from specialized centres to primary attention centres or homes. Besides, ICT

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allows these services being supported by families or even patients [4]. The Ambient Assited Living (AAL) initiative tries to offer an "active ageing", which treats elderly people as active participants of an inclusive society. Thus, AAL has one specific objective: to foster innovative ICT-based products, services and systems for ageing well at home, in the community, and at work, therefore improving the quality of life, autonomy, participation in social life, skills and employability of older people and reducing social and health care costs. AAL present the "well being person" as the centre-receiver of services set in the following scenarios: *Home Care, Health & Wellness; supply with goods and chores; safety, security and privacy; social interaction; information & learning; working life; mobility and hobbies* [5].

Nowadays, within the technological framework of ICTs there is a trend towards Internet-based technology services. Users request services with simplicity of use, reliability, security, support to be always well connected, and availability by mobile and fixed phone access with other services at the same time over the same device. IP Multimedia Subsystem (IMS) facilitates the development and the creation of multimedia services supporting interoperability and network convergence. IMS is a new architecture which promotes an interactive and personalized access to multimedia services over any device, and anywhere. IMS common functions called "service enablers" provides a "horizontal model" of service implementation, making a fast and solid service implementation by means of re-use of these services [1].

2 Methods

The aim is to show how services for ambient assisted living can be created or enhanced with IMS services resources. We present as examples a group of service enablers and some AAL services that can benefit from them to show the utility of IMS technology.

2.1 IMS Services

The IMS service enablers can be used by applications that implement one or several means of communication like voice and video call, messaging, and push to talk, in order to enrich multimedia sessions The most interesting IMS enablers selected among the ones available in ICT market [2][6] are the following:

- *Security and authentication (SA)*: provides a "single-sign-on" mechanism.
- *Active Address Book (AAB)*: can be updated independently of user location and/or access device, showing presence information of user's contacts.
- *Media handling (MH)*: users can share or transfer multimedia contents in a session (voice call, videoconference or chat session)
- *Mobility & Global availability (MG)*: An active connection across multiple access networks, with the same service over different devices.
- *Location-based (L)*: Users receive offers depending on their location.
- *Multiconference (MC)*: offers a (video) conference scenario between two or more participants.

2.2 AAL Services

The AmiVital Project CENIT 2007-2010 [7] defines a list of AAL services to cover all environments defined in the AAL program. Depending on the user scenario, we find the following services:

- *Home Care, Health & Wellness (HHW):* care prevention and promotion system; patient's health conditions and behaviour surveillance; medical home teleconsulting; shared-continued care by several specialists; electronic healthcare record access; home-caregiver support; doctor appointment management; medication and electronic receipt management; and health alarms management.
- *Supply with Goods and Chores (SG):* shopping, posting and cleaning services support; food supply services; and financial activities support.
- *Safety, Security and Privacy (SSP):* security alarms management; home accidents detection; home device detection and management.
- *Social Interaction (SI):* Virtual groups for people with the same condition, channel for people belonging to the same council or neighbourhood.
- *Information & Learning (IL):* training and education programs for ageing people, information about weather and outdoor conditions.
- *Working Life (WL):* promotion of collaborative work systems, continued work training and education support.
- *Mobility (M):* cognitive and physic rehabilitation system, public transport virtual assistant, neighbourhood virtual assistant.
- *Hobbies (H):* on-line games supply, information channels about activities in surrounding areas.

3 Results

IMS should help to move healthcare assistance to patient's environment (home, workplace, etc) for improving their conditions. In order to enhance the patient's autonomy, IMS can provide them with contents or services available in their current area or depending on their location. In that way, the interaction among elderly people is hardly promoted because they can share experiences by means of an enriched multimedia communication. The IMS sharing capability makes a collaborative framework possible where elderly people can develop their skills, or recover other lost abilities with rehabilitation exercises. On other hand, IMS guarantee the privacy and security of medical and confidential data avoiding possible intrusion in user's activities. Moreover, elderly people communication and participation in AAL services is promoted anywhere and over any device thanks to fixed-mobile access convergence provided by IMS.

The following table shows the map between enablers and AAL services, with the corresponding abbreviation mentioned before:

The criteria used in the mapping task have been by selecting those common IMS components which can provide benefits to AAL services or enhance their functionalities.

Table 1. Mapping table IMS enablers - AAL Services

		AAL Services							
		HHW	*SG*	*SSP*	*SI*	*IL*	*WL*	*M*	*H*
IMS enablers	*SA*	✓	✓	✓	✓	✓	✓	✓	✓
	AAB			✓					✓
	MH	✓			✓	✓	✓	✓	✓
	MG		✓	✓		✓	✓	✓	✓
	L	✓		✓		✓	✓		
	MC	✓			✓		✓	✓	✓

4 Conclusions

We have shown a conceptual example of how the features and services enablers provided by IMS can improve and enhance the AAL services implementation. Thus, IMS is proposed as a technology which can help developers to build services which cover elderly people requirements by means of a fast and solid service implementation, providing the "active ageing".

New services enablers could be defined depending on ageing people's needs, and new AAL applications new services enablers could be defined as well. Therefore, the AAL requirements would contribute to strengthen IMS technology.

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Enhancing OSGi: Semantic Add-ins for Service Oriented Collaborative Environments

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Abstract. Service Oriented Architectures offer an incomparable setting for the management and reuse of services, mixing different factors like software and services. The ability to choose between the services available often gets blurry, because of the difficulty when trying to find the best service that fits better the actual needs, or even because its invocation process gets excessively complex. This work presents a horizontal layer that enhances service capabilities in OSGi by adding semantic information for intelligent and advanced management in SOA-compliant smart architectures, and more specifically in a Multi-Residential Environment.

Keywords: Service Oriented Architectures, Semantic Services, Multi-Residential Environments, OSGi.

1 Introduction

Traditionally considered as a heterogeneous 'left-over' collection of activities that are not included in the agriculture or industry sectors, the services/software sector has, until recently, been a neglected area of economic policy making. As companies learn to trade products and services in new ways, often through Information and Communication Technologies (ICTs), services have become a pillar of the European economy [1]. In fact, every sector of the economy is moving (or planning to move) its business to the electronic way [2].

The 'Service' term often looks abstract, covering areas in different and heterogeneous sectors. The Service Oriented Architecture (SOA) approach covers perfectly this idea by creating new solutions centered in the service, the key piece for communications and value search of the mentioned actors in the structure.

But still, those services must be enriched in order to get the most of their potential and create truly scalable and healthy architectures. This work shows the addition of a semantic layer in the top of a Multi-Residential Gateway[3-5] SOA-compliant Architecture, based on the Residential Gateway approach [6]. It creates a horizontal structure for dynamic management and intelligent service provisioning, based on The

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Semantic OSGi Service Architecture [7-8]. It enriches service declarations, allowing intelligent and automatable searching and invoking processes, and can be applied to different SOA based environments in the actual computational structural model.

The paper is organized as follows: Section 2 presents the terms and challenges in the union of Software, Services and Semantics, showing the application of the Distributed Semantic OSGi service aRchitecture (DSOR) to a Multi-Residential real solution, while in Section 3 the main conclusions and future work are pointed out.

2 DSOR: Smart Services for Intelligent Environments

Services are the main piece in the service oriented puzzle, and the reason for the relationship established between Service Providers and Requesters. Initially solutions were made in an absolute ad-hoc way, providing strict, non-scalable, non-modular distributed applications. Nowadays, this situation is changing as more efficient solutions are being demanded by the Information and Services Society. Within this context, information needs to be processed in a ubiquitous and pervasive way, as well as interconnected by means of smart embedded computing, building up a new broadband ambient intelligent paradigm.

The DSOR solution is presented below, a service management solution that uses semantic technologies for intelligent service management in smart environments, and that has been successfully applied to a Multi-Residential Environment with MRG units.

2.1 Semantic Service Management + OSGi

Among the solutions proposed, the vast majority are based on the Open Standard Gateway Initiative (OSGi) specification [9-10], which promotes the dynamic discovery and collaboration of devices and services from different sources. The OSGi service framework provides a simple lightweight framework for creating service-oriented applications. Based on this framework, the use of technologies like web services is extremely useful and makes it possible to support interoperable machine-to-machine interactions over a network. The physical and logical infrastructure must be complemented with an intelligent service management architecture.

Several service management platforms have been created over the OSGi framework for distributed environments, using semantic technologies to index and catalogue the services that will subsequently be required by the different consumers in the scenario [11-12]. One of these solutions is the Dynamic Semantic OSGi Service Architecture (DSOR). The addition of semantic information to the OSGi registry was a need in order to facilitate the access through terms in shared vocabularies better than through interfaces and rough traditional programming.

DSOR provides an easy way to publish additional information about services, without modifying the default performing of the OSGi framework. DSOR supposes an evolution of the Semantic OSGi Service Registry (SOR), applying this semantic architecture to the scenario of the MRGs. It also complements the actual OSGi service registry, adding functionalities that do not prevent the default search and invocation engine of the OSGi framework. The SOR in-memory registry makes it possible, providing new searching capabilities that go further from local search and work, adding new layers to the OSGi architecture, without the need of any additional library bundle.

2.2 Annotating Services

The information about services in DSOR must be obtained from the services themselves. This solution makes use of the Java Reflection and the Java Annotation APIs to include the information in the source code and to obtain it later, during execution time.

In Fig. 1 an example about the annotation of a service in DSOR is shown.

```
@S3Method(domain="NetworkManagement",
        concept="add_vlan_interface",
        description="Add VLAN interface to a platform",
        arguments={
            @S3MethodArgument(order=1, concept="host_ip",
                description="Host IP address"),
            @S3MethodArgument(order=2, concept="vlan_id",
                description="Virtual LAN identifier"),
            @S3MethodArgument(order=3, concept="vlan_ip",
                description="IP address for the VLAN interface"),
            @S3MethodArgument(order=4, concept="netmask",
                description="Mask for the VLAN interface"),
            @S3MethodArgument(order=5, concept="interface_name",
                description="Interface name for the VLAN")
        }
    )
public boolean addVlanInterface(String hostIp, int vlanId,
    String ip, String mask, String ifaceName) {
{
```

Fig. 1. DSOR service annotation

Using terms in common shared vocabularies, this is the only coupling point required for the server-client sides to be able to cooperate in the architecture, avoiding the extensive use of Interfaces in the common operation mode of the OSGi Framework. Therefore, DSOR does not need to be directly referenced by the different service-providing and/or client bundles in the framework.

3 Conclusions and Future Work

In the same way as human beings establish a communication thank to language, the complexity in relationships at this level can be decreased with the understanding of certain terms in semantic and well defined sets. The system extensibility, by means of a shared use of resources, is one of the goals in Service Oriented Architectures. Reusability is pretty much a done deal with the correct definition of resources available in the cooperative network, being understandable by every involved part.

DSOR has finally got to be a horizontal solution with applications in heterogeneous projects. The addition of semantic information to services in the environment facilitates the client access through terms in shared vocabularies, better than through interfaces and rough traditional programming.

This way, new logic layers and inference engines can work together and be built in the Framework, in order to add as much complexity as needed in each case. This additional abstraction layer also adds many possibilities for scalability and update tasks in the solution, creating dependencies only at the time of creating the basic layers. It creates data dependencies only with a list of terms that can be updated and communicated with another vocabularies, forming the necessary consensus for both client and server parts.

The performance of the solution has also been evaluated through a battery of tests that consider different scenarios, getting execution times that vary from 30 milliseconds (in positive scenarios, in which services can be obtained) to 42 milliseconds (in the worst case, if the service can not be found, with one thousand different services available in the system). This has also helped to apply load-balancing techniques in the different developed architectures.

Regarding to the future work, the development team is, at the present, extending the system to make it compliant with external semantic service-providing source systems using OWL-S.

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Using Web Services for Medication Management in a Smart Home Environment

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Abstract. The Smart Home is a house equipped with technology to assist especially the elderly and persons with special needs. Smart Homes rely on Service-Oriented technology usually OSGi. Web Services (WS) receives little emphasis on Smart Homes, but they can be very useful for some applications. That is the case of management of medication as this task can become very difficult and involve different, remote parties. Several solutions have been proposed for applications like medications management but their lack of interoperability limits them. This paper presents a solution that integrates current systems and provides interoperability by using WS. The secure transfer of sensitive data among subsystems is achieved by using secure WS for communication purposes as shown by our prototyped implementation.

Keywords: Smart Home, Web Services, OSGi, Medications.

1 Introduction

The Smart Home (SH) is a house equipped with technology like sensors and actuators with the purpose to help the resident in performing their activities of daily living. SH research has focused on using these homes to help the elderly and person with special needs to stay home longer and live more independently. SHs have relied on the Service Oriented Computing (SOC) approach to simplify its design, shorten the development time and reduce the cost [1]. Different Service Oriented Architectures (SOA) has been developed. Two widely used SOA are Web Services (WS) and OSGi services. Both architectures are platform independent, rely on well defined standards and can be deployed over networks. WS has become very popular and most research in SOC has focused on WS. OSGi has become a widely used standard for applications that use embedded devices such as SHs. This paper shows that WS are very useful for certain SH applications especially remote applications and those involving third parties. The use of WS for certain applications certainly reduce the cost and development time as some of these services needed are already available.

One of these applications of WS within the SH is with the management of medications. Difficult prescription names, different instructions and the fact that a person

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might be taking several medicines at the same time can make this a difficult task especially for the elderly and persons with special needs. Using technology will certainly help this population to increase compliance and medication intake [2].

The SH environment can help with the management of medications. The authors in [3] provide a system called Medicine Information Support System (MISS) which integrates the doctor, the pharmacy and the SH to increase safety, manage the medications and increase medication intake and compliance. This system requires little action from the SH resident as it takes care of the process in a transparent way. This paper integrates WS technology with the MISS system to make it more interoperable, expandable and platform and language independent. The rest of this paper is organized as follows: Section 2 contains related work. Section 3 provides more details on the MISS system and how it was expanded by using WS. Section 4 details the prototyped implementation of this system. Section 5 contains the conclusion and future work.

2 Related Work

In [4] the author explains how today's devices are more powerful with more computational and communication power allowing this technology to be used in home applications. However these devices and appliances use different protocols, a lot of them proprietary. They proposed a solution based on WS to achieve interoperability, heterogeneity and scalability. They implement the WS stack in the devices or in the devices controller. Their main purpose for bringing technology into the home is to help the elderly to stay home longer, having the necessary assistance and reduce the learning curve, sharing a similar motivation of this work.

Even though in [4] the authors propose a solution based on WS for SH applications, in general SHs rely on the OSGi service platform [5]. Both technologies offer a set of unique features, so the combination of them can help providing new solutions. In [6] the authors describe a driver on top of OSGi in which devices can be dynamically added, invoked and mapped to different WS standards. Their vision is to have a centric platform in which the functionalities are provided as services and applications compose these services in a flexible way. The OSGi platform is used and drivers on top of OSGi are developed to support WS. Each WS is mapped into a service in the platform. This is a good attempt in trying to combine both technologies together but full integration it is still needed [7].

3 OSGi and Web Services in the MISS System

The Medicine Information Support System (MISS) is a system that helps patients to manage their prescriptions [3]. It improves safety by checking for conflicts among medications, health conditions and food. The way it does it is by integrating the doctor, the pharmacy and the SH in such a way that prescription information is forwarded from one subsystem to the other. It uses a trusted third party that defines the conflicts among medications, health conditions and foods. Prescriptions data is checked against the patient's data stored at each subsystem to identify any possible conflicts. The next few paragraphs briefly summarize MISS and how we applied WS to it.

The doctor subsystem is where this process begins. The doctor enters the prescription details with the medications and dosage information. The doctor is assumed to have a record of the previous prescriptions and health conditions of the patient. The patient's record is checked against the new prescription to determine if a conflict exists. To detect a conflict we use a trusted third-party such as the Food and Drug Administration (FDA) or the Physician Desk Reference (PDR) who defines conflicts among medications, conditions and foods. After this check, prescription data is forwarded to the patient's preferred pharmacy via a secure communication channel.

The pharmacy subsystem performs a similar function of checking the prescription for conflicts with other medications. We assume that the pharmacy keeps a record of all medications previously picked up by the patient. A check for prescription conflicts is performed using the patient's data at the pharmacy and a trusted third party such as the FDA or PDR. If no conflicts are found a secure channel is used to forward the prescription data to the SH.

The SH subsystem performs a similar check for conflicts. It is assumed that the SH keeps an inventory of the medications and the food at home. The SH then check for conflicts among medications picked-up from different pharmacies and with food at home. Again a trusted third party defines the different conflicts.

The MISS system assumes a secure communication channel for forwarding data from the doctor to the pharmacy and from the pharmacy to the SH but no details of this secure channel are provided. One way this secure communication channel can be implemented is by using WS which will also make the different subsystems interoperable as WS are platform and language independent, a main feature of this technology [9]. This will allow for current system to keep working but also to be expanded by using this technology.

This work extends the MISS system by making WS a fundamental part of it. MISS makes use of stand-alone applications for the doctor and the pharmacy subsystems. It uses OSGi services at the SH to control the devices and application. This work uses WS to glue these three subsystems together providing interoperability and preserving the platform and language independence. It also allows other applications to use the Web Service provided if needed. This approach takes care of providing a secure mechanism for forwarding data among subsystems. The next section has a summary of a prototyped implementation of MISS using WS.

4 Prototyped Implementation Using Web Services

A prototyped implementation using the approach described above has been implemented in our SH Lab. For the doctor's subsystem an application has been developed in which the prescription details are entered and then forwarded to the pharmacy using a secure WS provided by the pharmacy that the doctor's subsystem invokes. The pharmacy WS provide the tools for the doctor to forward the prescription's data. When a prescription's data is received via this WS, the data will be transferred to the pharmacy's main system so that the pharmacist can starts preparing the prescription. When the prescription is ready the pharmacy subsystem use a WS provided by the SH to forward the prescription data from the pharmacy into the home system. This WS will allow data to be transferred from the doctor's subsystem to the SH also, such as medical conditions. This allows the SH to have more data available and perform and final and more complete check for conflicts which will improve safety.

5 Conclusion and Future Work

The SH is a house equipped with technology to help the elderly and person with special needs to stay home longer. One way to help this population is with the management of medications. This is a task that can become difficult given the amount of data that needs to be handled. To increase compliance and medication intake several solutions have been proposed but the lack of a universal platform and language independent approach limit these. This paper presents a solution that integrates current systems and make use of service oriented approaches specifically WS. Future work includes the use of formal methods to validate that the data is transferred correctly, that privacy is respected and that the entire system performs its intended functionality. Also full integration among SOA such as WS and OSGi and the use of some WS sub-languages is something we would like to do in the future.

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Service Reconfiguration in the DANAH Assistive System

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Abstract. Smart Homes are pervasive systems that interact with the user using a service offer paradigm to provide fully automated daily repetitive tasks. When services are augmented with semantic relationships, one can build adaptive services and systems. In this paper we deal with service failures and propose a recovering method, which we call service reconfiguration, to ensure service availability in smart homes. Both off-line and on-line reconfigurations are considered. This method has been implemented in the DANAH assistive system.

1 Introduction

Assistive technology systems (ATS) are a kind of pervasive systems that help dependant people improve their lives. The Smart Home concept [4] emphasises on environmental control by incorporating electronically controllable devices and sensors to provide automated services and monitoring.

The DANAH assistive system is a software application that helps the elderly and the disabled turn their living spaces to entities that provide assistive services. Within automated homes or medical structures, users can benefit from daily automated tasks using a human machine interface simply by selecting the service they want, and DANAH shall deliver it for them.

In the context of these intelligent environments, we aim at ensuring service availability in the presence of failures through *service reconfiguration*.

This paper is structured as follows : Section 2 introduces service reconfiguration. Section 3 presents the DANAH assistive system. Section 4 presents addressed service failures and the reconfiguration process. Finally, we conclude our work and present eventual perspectives and future work.

2 The DANAH ATS

2.1 Architecture

The DANAH Assistive System [1] is a modular distributed assistive system that allows the disabled and the elderly to interact with their environment using a service offer paradigm, achieving *environmental control*. It relies on three entities : Servers, Clients and Automation Technology as depicted in Fig. 1. *Servers*

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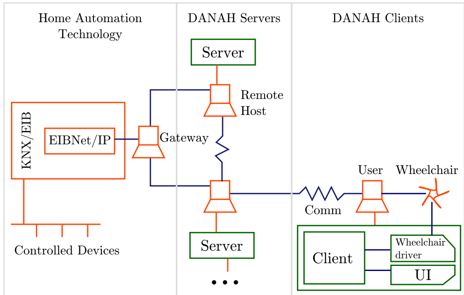


Fig. 1. DANAH architecture and HW/SW mapping, using the KNX/EIB Home Automation Technology

and deployed in the environment and contain information about the topology and the services they locally offer. A *Client* establishes a connection to a server and gets a list of the available services (pull-mode).

2.2 Resources, Operations and Effects

Resources are DANAH representation of controlled home hardware, such as doors, lights and TVs. A resource is advertised using its *name* and has a status stored in its *properties* which are key-value pairs. It contains *operations* that represent the services it provides (e.g. 'On' and 'Off'). A *runtime* is responsible of executing operations and updating resource status. Communication between the runtime and the physical device is achieved using a *protocol*. Resources are linked to the environment topology through *activation nodes* that specify at which areas operations can be delivered. Finally, resources are *tagged* by keywords that inform about their characteristics.

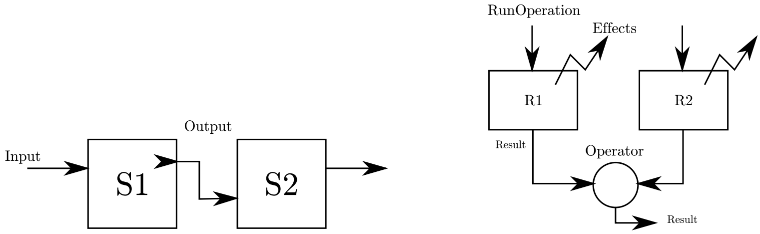
Operations can be *runtime controlled* (atomic) or *composite*. Atomic operations are directly run by calling appropriate method within the runtime. Composite operations are operations described using literal expressions, as shown in Fig. 2.

```
operation "Enter" { expression="SEQ(Door.Open Light.On)" }
```

Fig. 2. Composite Operation 'Enter' uses two atomic operations

Unlike in traditional service oriented applications, invoking a resource operation does not require input data. Instead, *effects* on other resources are produced, as depicted in Fig. 3.

The *effect* [2] [3] of an operation is what is perceived by the user. Its principle is that running a resource operation can have effects on one ore more resources. Effect computation is performed using resource runtimes and *effect rules*. The runtime is responsible of computing the effects of the resource's own operations.



(a) Standard service mechanism (b) Service mechanism DANAH

Fig. 3. Composition schemes in traditional applications and in DANAH

Then using effect rules, DANAH computes the overall change on other resources. An effect rule consists of a *precondition* that if satisfied triggers its corresponding *postcondition*, as shown in Fig.4.

```
effect {  pre="MainLight@Status==On"
           post="this@Illuminance=100"}
```

Fig. 4. An effect rule

3 Service Reconfiguration

3.1 From the Request to the Provision

A *service* can be an operation, a composition of operations or an objective to reach (e.g. `Room@Temperature=25`). When it is requested, DANAH starts by performing a *syntactic expansion* which recursively replaces composite operations by their corresponding expressions, and dynamically resolving objectives into a set of operations. To run an operation, DANAH performs navigation to the resource by choosing one of its activation nodes (if any) and finally activates it with the help of the automation technology. Whan an activation fails, it triggers service reconfiguration. Reconfiguration can be either static using off-line rules or dynamically computed at runtime.

3.2 Static Reconfiguration

Static reconfiguration is triggered on activation failure. It uses static rules defined in resource descriptions. When the activation of an operation fails, DANAH searches in all resource descriptions for an alternative expression that may replace the defunct operation, as shown in Fig.5. It says that when the turning on the main light fails, the system must fall back to turning on the two alternative lights.

Static reconfiguration rules are convenient ways for the user to set its own reconfiguration preferences, since it has priority on any dynamically computed alternative.

```
reconfiguration { fail="MainLight.On"
                  alt="SEQ(AltLight1.On AltLight2.On)" }
```

Fig. 5. Static reconfiguration rule

3.3 Effect-Based Reconfiguration

Effect-based reconfiguration is triggered on activation failure, in the absence of static reconfiguration rules. The aim of effect-compensation procedure is to compensate the effect the failed operation should have produced on other resources using one or several other operations from different resources.

When an operation is run, the resource's properties are first updated by its runtime. Then using effect rules, these property changes may satisfy preconditions that trigger other changes in other resources, as depicted in Fig. 6.

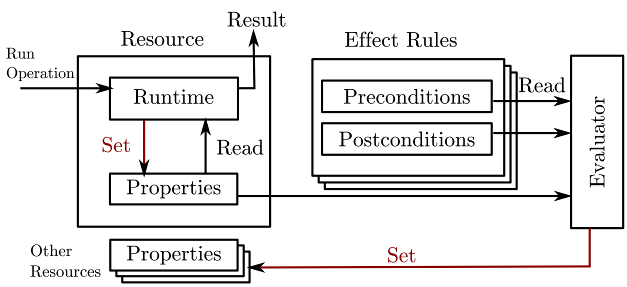


Fig. 6. Effect update mechanism

When an activation fails, effects of the failed operation are searched and compensation is performed for each affected resource. This is done using a 'dry run' mechanism that selects the operations which change the considered effect and fakely running them. At the end, the sequence that produces the closest effect that the one that is expected is suggested as an alternative.

4 Conclusion

In this paper we described the service reconfiguration in the DANAH assistive system, which aims at ensuring service availability in case of failures. Addressed failures are operation activations. Static reconfiguration is used on activation failure and relies on off-line reconfiguration rules. Effect-based resource linking has been introduced and used to perform effect compensation, possibly using several operations to compensate the effect of a single one.

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Model-Driven Development Approach for Providing Smart Home Services*

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Abstract. Smart home is about the application of automation techniques for the comfort and security of residents' privately owned homes. In a smart home environment, different and independent embedded devices provide services that can be freely used by others, in the sense of service invocation. This paper presents our idea of using Model Driven Development (MDD) for the composition of existing services, by which we aim at demonstrating how new smart home services will be promoted.

1 Introduction

The internet is becoming an important infrastructure for the growth of the today's economy and society, where the infrastructure itself is also growing continually. The future internet is environments where all Internet resources (users, media, services, devices, and networks) are convergent. Different and independent computing devices from small embedded devices (mobile devices, embedded systems, etc) to powerful (desktops and servers) are easily connected to the network and are used to access services. This situation seems to happen in home environments, which introduces a smart home system, which is typically shown in Fig.1.

A residential gateway (RGw) connects the home network containing different embedded devices (and services) to the Internet. As an example, three different entities are shown; a service provider that provides an SMS web service, a UPnP-based television that provides a display service, and an OSGi-powered RGw [15] that hosts services such as alarm system, internet connection, and UPnP devices detection. We consider all those services to be basic services in which we can promote a new advanced service by means of service collaboration of those basic services. The new service may include multiple devices, both internal services in the home network and external services outside the home network.

There are several ways to compose (create new) services at the design time. OMG's Model-Driven Architecture™, MDA [1], is a general approach for building distributed heterogeneous systems. We demonstrate in this paper, how the MDD approach can be applied to the development of smart home services, to increase the number of services which are installed in a residential gateway. For this purpose, we use a case study of developing a mobile-based smart home service.

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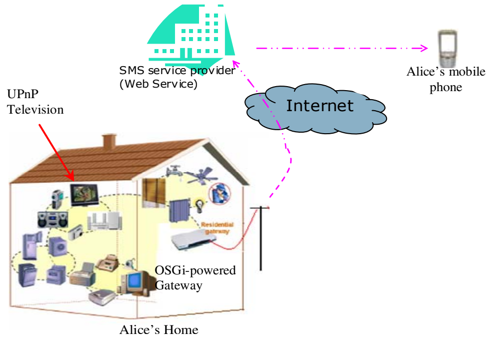

Fig. 1. Typical smart home systems

The rest of the paper is organized as follows: Section 2 gives an overview about the model-driven service composition. We present the case study of service collaboration in Section 3. Finally, we draw our conclusions and present future work in Section 4.

2 Model Driven Service Composition

Service development by means of service composition is gaining importance, as it can produce composite services with features not present in the individual basic services. Several methods, framework and tools of service composition in a smart home environment have been proposed over the years to address these issues [3][4][5][6]. In [6], for example, they developed a framework to implement the service composition of networked home appliances and entertainment. However, none of them use MDD. It is described in [7][8] how the MDD approach can be used to compose services, but both are focused on web services and did not consider services in a home network.

The service composition is mainly done in three steps. **1)** Abstraction of existing run-time services description. For this we represent the service descriptions using a graphical representation (building blocks). The abstraction gives also templates that are used for source code generation. So, a building block includes information about its services, where the location is, and which template of source code to use. **2)** After we abstracted all the existing services we want to use into building blocks, the modeling of the new service can be started. As we mentioned, the modeling of the new service will focus on the collaborations activities only. **3)** Finally, the models are transformed into an OSGi bundle using a template-based source code generator. Different targets should easily be changed.

Within the ISIS project [9], a tool called ARCTIS [2], which is built on UML 2.0 and is a part of the SPACE [10] approach to services design, has been developed. The services are modelled in terms of **building blocks**. A building block has input and output pins to represent required and provided services. In this way, the service composition is done by connecting two or more building blocks.

3 Case Study: Mobile-Based Alarm Service

In this scenario we developed a new mobile-based smart home service that enables the owner of the house to get the status of her/his home's equipments (represented by sensor in the- alarm system) wherever she/he is. It could be *health-related* equipments.

In this case, an alarm message will be displayed onto either a UPnP-based television when the owner is at home or on his/her mobile phone when the owner of the house is not at home. The new service which is implemented as an OSGi service is based on the existing services; OSGi services, UPnP services, and a SMS Web Service. We used Cybergarage UPnP [11], Knopferfish OSGi[12], *sendSMS* Web Service [13]. The first step is service abstraction in terms of ARCTIS building blocks. There exist several frameworks of service description, publishing, and discovery, for example, WSDL(Web service description language), UPnP, and OSGi. Based on the service descriptions we develop building blocks, to implement the service invocations.

After all the existing services we want to include in the new service have been abstracted into building blocks WSDL, UPnP and OSGi in terms of ARCTIS we can model the new service, both the structural and behavior aspects. Figure 2 below shows the block diagram of the new service. The new service, alarmService, which in ARCTIS uses a <<system>> stereotype, is a collaboration service of three different services (the display services, the SMS Services, and the alarm service).

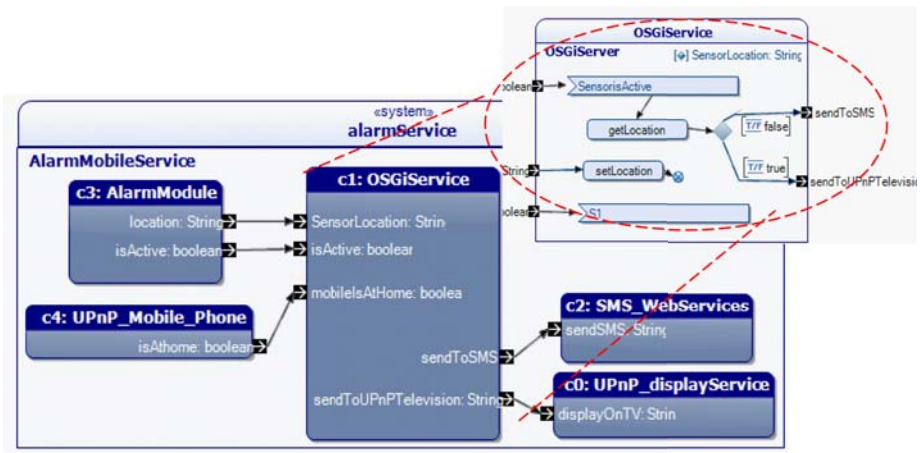

Fig. 2. The new mobile-based alarm service

The internal behavior of the c1:OSGiService is an activity diagram that describes how the service works. When a sensor is activated, the c1:OSGiService will search the location of the sensor and detect the presence of the mobile phone. If the mobile phone is at home the message will be sent onto the UPnP-based television. Otherwise it uses the *sendSMS* service to reach the mobile phone. And. finally, the transformation of model to code is done. A template-based source code generator was built using JET [14]. Obviously, there is a relation between the source code generator and the templates in the repository.

4 Conclusion and Future Work

We have demonstrated the MDD approach for developing a smart home service by composing three different service kinds in different computing devices; UPnP services, OSGi services, and Web Services. The new mobile-based smart home service is an OSGi service which is intended to run on an OSGi-powered residential gateway. In the future we will explore automatic wrap to extract building blocks from existing services. Moreover we will use more complex services.

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LET_ME: An Electronic Device to Help Elderly People with Their Home Medications

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Abstract. Recent literature reports on high adverse events rate, especially among elderly people, due to bad self-administration of their drug therapy. They make errors taking wrong drugs, or taking drugs with incorrect dosage and frequency. These "*therapy errors*", in the USA, cause about 3,000,000 hospital admissions each year. Within the medical informatics community, different research groups are developing computer-based support systems addressing this problem. This paper presents a novel approach in this area, and describes a device to make home drug therapy as safe as possible. The system designed took into account the whole process, starting from drug prescription by the general practitioner, to the drug acquisition to the chemist and, finally, to drug assumption at home.

Keywords: Therapy errors, medication errors, administration errors, non-compliance, home therapy, elderly people.

1 Introduction

Since the '60s the number of publications about errors due to wrong use of drugs is constantly increasing. Many of these papers talk about the high mortality rate, and especially among elderly people, due to bad self-administration of their drug therapy. Recently, a number of new devices have been developed to help elderly people take their medicines, but the novelty of this project regards the whole context related to the home drug treatment: it considers the roles of general practitioners, specialists, pharmacists, and of course the patients themselves.

A *therapy error* is any predictable event that can cause the incorrect use of a drug or a damage to a patient when the drug is under control of caregivers or the patient himself[1].

These errors can happen in every moment of the drug management process and can be classified as[1]: *prescription errors*, *transcription errors*,*therapy preparation errors*, *administration errors*, *dispensing errors*. Another potential issue of the home treatment is caused by drugs that do not require prescription. Self-medication can improve the attention for one's own health, but it can also increase the probability that self-prescribed drugs are used incorrectly, modifying the effects and safety, increasing the probability of ADEs (Adverse Drug Events) due to drugs misuse.

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Often elderly people self-manage their drugs, and errors are caused by memory problems, unavailable prescriptions, and/or lack of understanding of the treatment regimen. Increasing the number of contemporary drugs or the assumption frequency of drugs, increase the errors that they can make[3,2].

The organisation of the paper is: in the following section we illustrate the project and some applications; and then we present the conclusions and future works.

2 LET_ME

The name of our device is *LET_ME* (from the Italian words LETtore di prescrizioni MEdiche; in English: reader of medical prescriptions). The final user of this device will be the elderly or, in general, people with memory problems that must follow a home therapy, their caregivers, and people with drug allergies. LET_ME is a PDA (Personal Digital Assistant), equipped with 2 reader: a bar code reader used to identify the drugs by means of a special kind of bar code, called *farmacode*; and an RFID reader to identify the patient, that is supposed to wear a simple wristband. This functionality is necessary when more than one patient use the device in the same home (e.g., husband and wife). The proposed system needs information about drugs marketed in Italy, and so the database used in this project has been supplied by "Farmadati Italia S.r.l.".

LET_ME has two modalities: *programming modality* and *user modality*.

2.1 Programming Modality

The programming can be made by the prescribing doctor or by the pharmacist.

1. Programming by *the prescribing doctor*. The patient goes to the doctor bringing the LET_ME with him. The doctor repeats for all medicines:
   – using his PC, writes and prints the prescription;
   – then, he prints the bar codes of the prescribed drugs with the same computer procedure. Referring to the pharmaceutical label, he must print the bar code on the new adhesive label representing the A.I.C. code and the drug name. In addition, the text "LET_ME PROJECT" will be printed to explain the presence of the new label, in case patient drug boxes are checked for legal reasons. Next steps are:
      • the doctor reads the A.I.C. code using the bar code reader;
      • LET_ME recognises the code, by searching into its drug DB, and displays it with the corresponding drug name;
      • the doctor assesses dosage and time, or frequency. To make this programming phase as much smooth, speedy and safe as possible, the device can: show standard dosages and timing reported in the DB for all the pathologies/symptoms curable with this drug; allow to modify dosages and/or timing displayed at the previous point, by pressing few buttons; verify possible presence of components that

can cause allergy or intolerance to the patient, possible interactions with drugs already stored for the patient in the patient's active list, to show possible drug-food and drug-drink interactions.
- when the prescription is completed it is stored into the patient's active list, which is integral part of DB;

Also, the doctor can update previous prescriptions.

2. Programming by *pharmacist*. The programming will be done by the pharmacist when the patient goes to the doctor forgetting the LET_ME, following doctor's instructions about drugs, dosages and frequencies. If, among the prescribed drugs, there are some refundable medicines, the pharmacist removes the original farmacode labels, and replaces them with the ones printed by the doctor. If the patient buys drugs on his initiative, for example O.T.C. (Over-The-Counter) or S.O.P. drugs (Senza Obbligo di Prescrizione; in English: without prescription obligation), the pharmacist will not do anything.

Checks. LET_ME carries out four checks. With the first one, it checks whether the drug is already stored. The second check controls the drug components to which the patient is allergic or intolerant (e.g. penicillin) The third check controls that the active principle is not in "conflict" with the other active principles already present in the current patient's treatment. In this case, LET_ME displays a message which says that the drug can not be administrated combined with the other one and if the programmer is the doctor, he decides how to proceed. If the programmer is the pharmacist, he will stop programming and contact the doctor. The last check regards drug-food interaction and drug-drink interaction, in order to avoid alteration of the expected drug effects. The device verifies if the drug must be taken "on a full stomach" or "distant from mealtimes" and if some particular food and/or drinks can modify the therapeutic drug effects.

An example of a drug-drug interaction check: we suppose that among drugs present into patient's active list there is the "SIVASTIN 28 CPR 20 MG RIV", the allergy list is empty, and the doctor prescribes to the patient the "LIPOZID 30 CPR 600 MG". LET_ME checks if this drug is already stored in the patient's active list, and it is not, then it checks drug-drug interactions, and it finds that an interaction exists between SIVASTIN active principle (simvastatin) and LIPOZID one (gemfibrozil) and so the device shows on the screen a message such as: "The drug contains gemfibrozil that interacts with simvastatin, and so this drug can not be prescribed since the patient is taking SIVASTIN 28 CPR 20 MG RIV".

2.2 User Modality

When the patient is at home and he needs drug information, he turns on the device and moves the package near the reader. Then, LET_ME shows the prescription stored, with the following information: name of medicine; dosage; time or frequency; note about food and drink. Pressing the AUDIO button, the displayed information can be listened through a synthesized voice. This is useful for patient with eye problems, that are known to be an error source too[4].

If the patient uses LET_ME with a O.T.C. or S.O.P. drug, we have two cases:

1. this kind of medicines were prescribed by the doctor and so LET_ME has a stored regimen about them;
2. they were bought from patient on his initiative and so LET_ME does not have regimen, or they were bought in shop different from a pharmacy.

Let us focus on the second case. Patient holds the "TACHIPIRINA 20 CPR 500 MG". Patient turns on LET_ME, which reads the farmacode; LET_ME seeks the drug into the patient's active list and does not find it. So the device makes a search into its DB to see if the drug is an O.T.C. or a S.O.P. Then, LET_ME extracts the active principle of TACHIPIRINA, i.e. paracetamol, and checks for drug-drug interaction with the medicines stored into the active list. We suppose that into the active list there is "TEGRETOL CR 200 30 CPR 200MG"; its active principle is the carbamazepine which interacts with paracetamol, so LET_ME shows: "This drug contains paracetamol that interacts with carbamazepine, so this drug can not be taken because TEGRETOL CR 200 30 CPR 200MG is in your therapy".

3 Conclusions and Future Works

The aims of this new device called LET_ME are: improving medication adherence and safety in the administration of medications; reducing hospitalizations, and consequently healthcare costs. Compared to the existing tools, LET_ME: allows patient's doctor to keep under control all the prescribed drugs, avoiding dangerous drug-drug interactions; it can be used by more than one patient, thanks to an identification wristband; it gives information about food and drinks that could interact with the patient's drugs.

Now, we plan to evaluate the system in two phases. First, with some subjects volunteers, to test the reliability of the device, its usability, discovering bugs. The second phase will be a trial with more subjects. These subjects will be subdivided in two groups: the first will use this device and the second one (the control group) will not use it, to prove the efficiency.

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Preferences of Healthcare Staff in the Way of Interacting with Robots Depending on Their Prior Knowledge of ICTs: Findings from Iward Project

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Abstract. Research about applicability of robots in the healthcare sector is constantly increasing. IWARD is a EU 6th framework project to directly support staff in hospitals by a self-organizing swarm system that will provide an efficient way to order specific tasks without worrying about the details of their execution. The IWARD swarm will be able to perform delivery, guidance, cleaning, monitoring and surveillance tasks. In order to develop a swarm that works for hospital staff, User Centered Design (UCD) was chosen, as this approach provides the developers with a better way to identify with end users when trying to develop a design for them. Keeping this perspective in mind, the following paper describes the process and methods of gathering information about heath care staff attitudes and expertise towards technology and robots, and how these features may facilitate or interfere with the subsequent inclusion of IWARD technology in hospital environments.

Keywords: Assistive, robot swarm, healthcare, User Centered Design, attitudes towards technology.

1 Robots and Healthcare Sector

Research about applicability of robots in the healthcare sector is constantly increasing [1], [2] and [3]. IWARD (Intelligent Robot Swarm for attendance, Recognition, Cleaning and delivery) is a EU 6th framework project to directly support staff in hospitals by a self organizing system that will provide an efficient way for users to order specific tasks without worrying about the details of their execution. The swarm-paradigm based system not only ensures the cooperation and communication among the robots, but also provides a homogeneous interface to staff. The tasks that the IWARD swarm will be able to perform are Delivery (delivering items within the hospital –e.g. deliver drugs from the pharmacy to a specific ward.), Guidance (guiding people inside the hospital from one location to another), Cleaning (unexpected cleaning such as different types of spillage), Monitoring (control patients' behavior, blood

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pressure, temperature, and so on) and Surveillance (control environmental variables as smoke, fire or possible intruders in restricted areas).

2 User Centered Design and Virtual Personas

Due to the interest of the members of IWARD project to develop a swarm that works for hospital staff (and not a hospital staff who works for the swarm), User Centered Design (UCD) was chosen. The advantage of using UCD is that having a large number of data does not help much because there is a risk of being lost among so many details. But, with the use of UCD and creating virtual personas, it is easier for developers to identify themselves with virtual personas and try to design for them [4].

Because of this, several persons of the Matia hospital staff in San Sebastian (Spain) were interviewed with the aim to create virtual personas to help developers know which kind of people they are developing the technology for. After this process, three virtual personas were created (Saioa, Izaro and Nagore). When virtual personas were built, three different user profiles were found:

- Those who are experienced in the use of technology and want to learn about them.
- Those who are not experts in the use of technology but are willing to learn if that is helpful for their work.
- Those who are not experts in the use of technology and do not want to learn the use of technology. This type of virtual persona is called antipersona.

As an example brief descriptions of the first and third type of personas are presented below (as examples of opposite attitudes and expertise).

Persona #1. Experienced with technology: Saioa is 41 years old nurse in a long term care hospital. Saioa is used to work with Information and Communication Technologies (ICT). She uses her computer everyday and has no difficulty using technologies like photocopier, printer, fax, mobile, DVD or a camera, but she has never used a PDA or an electronic reminder, though she is willing to learn how to use them if that helps. When she speaks about robots for elderly or disabled people, she thinks that they should not be very big and that they should be easy to control and clean. She would like to control them remotely. "*I think it shouldn't look like a robot; some people are afraid of them. I think they should look like humans*", she says.

Persona #3. Nagore doesn't know how to use the most of ICT devices and has no intention to learn how to use them because as she says: "*Computers are so cold...*" and if someone tries to speak with her about robots, her answer is: *"Robot? It would scare my patients… and me too. I don't even want them in a film"*.

3 What Does the Final User Tell Us?

After using virtual personas to have a general idea about the final users, a new questionnaire was created in order to know which way the final users prefer to interact with the robots. Our initial hypothesis was that the way the hospital staff will want to interact with the robot is closely linked to their knowledge of current technology. The procedure to know which could be the best way to design the interface of the robot consisted of interviewing hospital staff in order to have an idea about (1) which are the devices they are used to use in their daily work and (2) which of those devices they prefer to use in each of the interactions with the robots. For this purpose, 40 people were interviewed 10 in San Sebastian (Spain), 10 in Warwick (UK), 10 in Newcastle (UK) and 10 in Sakarya (Turkey). The sample was made up of different workers of the hospital (pharmacists, auxiliaries, nurses, doctors and so on). Parametric and non-parametric statistical analysis have been computed in order to know if there are differences between people who have no experience in the use of technology, those who have some experience and the ones who commonly use technology.

First, for the analysis of the most relevant differences in the preferences of hospital staff, their experience on the use of a computer was taken into account. Here, two groups could be differentiated: people with Some Experience (SE) and people who Commonly Used (CU) computers. Thus, everybody reported at least some experience with computers. The importance ranged from 1 (least important) to 5 (most important). These analysis show statistically significant differences in favor of the CU group when compared to the SE group in terms of the importance they give to including a Touch screen mounted on the robot to interact with both the Delivery robot ($\bar{x}$=4.07, sd=1.223; p=0.01) and the Cleaning Robot ($\bar{x}$=4.17, sd=1.104; p=0.017), to use a display to both know the completion of the delivery task ($\bar{x}$=3.97, sd= 1.426; p=0.050) and to be notified of the robot's recognition of a situation ($\bar{x}$=3.83, sd=1.537; p=0.033). These results show that hospital staff members who usually use technology get significantly higher ratings, which means a better predisposition to the use of technology and to change the way they work now. It also can be seen a greater willingness to control what happens in the hospital they work.

Second, most relevant differences in the preferences of hospital staff taking into account their experience on the use of PDA touchscreen were analyzed (three groups were differentiated: NE=No Experience, SE=Some Experience and CU=Commonly Used). The importance ranged from 1 (least important) to 5 (most important). Results show that the CU group significantly prefers a PDA touchscreen and displays, more than the other groups, in order to initiate the delivery system ($\bar{x}$=4.78, sd=0.44, p=0.001), to interact with the delivery robot ($\bar{x}$=4.67, sd=0.707, p=0.017), and with the cleaning robot ($\bar{x}$=4.67, sd=0.707, p=0.036), and to be notified of the robot detecting unsafe environment ($\bar{x}$=4.67, sd=0.5, p=0.012), of its arrival at its called/destination position ($\bar{x}$=4.56, sd=0,527, p=0.009), and to know the completion of the guidance task (x=4.67, sd=0.5, p=0.036). These results may be because those who usually use this technology know the possibilities and therefore value the possibilities offered by technology. By contrast, those who have some experience in the use of technology know some of the options that technology offer, but are aware that this requires a period of learning that can be hard.

Finally, regarding the differences in the preferences of hospital staff taking into account their experience on the use of PDA sound/speech (NE=No Experience, SE=Some Experience and CU=Commonly Used), the results show that the CU group significantly prefers to use a PDA sound/speech, more than the SE and NE groups, to know the completion of the delivery task (x=3.83, sd=1.467, p=0.048), to complete the cleaning task and to get notified (x=3.92, sd=1.379, p=0.037) and to get notified about the robot's arrival at its called/destination position (x=3.92, sd=1.311, p=0.027).

4 Conclusions

Overall, results show that those workers who commonly use technology have significantly higher scores in terms of their openness to accept the latest technologies and incorporate changes in the way they work, than those who have some or no experience using technology. From our point of view, these results demonstrate, at least, two situations. (a) Technology cannot be successfully designed and developed if final users are not really taken into account. Hospital staff knows much better than robot designer all the distinctive features of the everyday activity in a Health Center. (b) The use of a unique way to interact with the robot is not a good idea. Some hospital staff is more used to work with a phone, some with paper and pencil, and some with a computer or with a screen. Developers should keep this in mind, since providing a unique way to interact with the system will probably cause more errors.

Considering this, there are two options when a new device is developed: (1) to create technology without taking into account the final user and provide training to workers to learn how to use it. It could happen that, at the end of the development, when technology is shown to final users, they are unable to understand the procedures to use that technology and may feel discouraged and unwilling to use it; and (2) develop technology after hearing what the final users have to tell about their preferences, needs, fears, the peculiarities of their work, etc. and adapt technology to them. Because in the end, nobody knows more about their work than the workers themselves. For this project, we have chosen the option 2. Whether the use of this approach will let us reach the desired results in terms of usability and adaptation to the end user needs and abilities is a matter of time.

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Research and Development Pathway of Rehabilitative and Assistive Robots at National Rehabilitation Center in Korea

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Abstract. In Korea, Research Institute of the National Rehabilitation Center is recently built up to improve the quality of life for the disabled. We shortly review rehabilitative and assistive robots with their core technologies. Then, the research and development pathway for those is described.

Keywords: Rehabilitative Robot, Assistive Robot, Human Machine Interaction.

1 Introduction

Improving the quality of life for the disabled is one of crucial issues over the world. More than two millions registered disabled persons live in Korea according to a survey [1]. The half of them is the physically disabled and their significant causes are posterior causes (89%) due to accidents and musculoskeletal system diseases. The persons with disability need rehabilitation and caregiving in their daily life. Robots would chiefly offer solutions to rehabilitate and assist the disabled in the near future.

The robots for the disabled consist of rehabilitative robots and assistive robots. Rehabilitative robots are generally applied to recover basic functions and improve the potential of the disabled by robotic systems in order to perform specific tasks especially for the medical treatment or therapeutic objectives [2], e.g., therapeutic exercise for walking. Assistive robots are usually used to help persons who perform the activities of daily living, such as eating and mobility.

Rehabilitative and assistive robotic systems have been primarily developed since late 1980s or early 1990s in order to condense the effort of caregivers and acquire the independent life [3, 4]. Basically, the physically disabled persons require two functionalities: the mobility and the manipulation. In case of manipulation, MIT-MANUS [5] is an exemplary rehabilitation robot for an upper limb of the disabled. Assistive Robot Manipulator [6] is a kind of wheelchair mounted assistive robots. In case of therapeutic robots, entertainment like video games seems to converge with rehabilitative training and those markets gradually increase.

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National Rehabilitation Center (NRC) in Korea recently launches Research Institute (RI) for the disabled in November, 2008. NRC includes the rehabilitation hospital for the disabled, such as spinal cord injury, stroke, and brain injury patients. Major research fields of RI, NRC are as follows: rehabilitative and assistive technology, motor and cognitive rehabilitation, and rehabilitation standard & policy. The major application area of rehabilitative and assistive technology includes general assistive technology, robotics, and vehicles for the disabled.

In this paper, we concentrate on the assistive and rehabilitative robots. In Section 2, we will review and make comments the current technology statuses for rehabilitative and assistive robots. The Research Institute's R&D issues will be proposed in Section 3. Finally, we will make the conclusion in Section 4.

2 Current Statuses for Rehabilitative and Assistive Robots

Assistive robots have following requirements. First, the price of a robotic system should be cost effective. Second, the robotic system should have light weighted body. Third, the overall size should be compact and easy to park a robot in a suitable location during the unused situation. Fourth, the energy consumption should be minimized. However, in case of rehabilitative robots, the reliability of systems is the most important issue in comparison with price, weight, and overall size. Safety and easy-to-use are essential issues for the consumers' points. Moreover, users' culture is considered one of unavoidable issues. During last one decade, the related component techniques have been improved: low power consumption of personal computing, effective actuator, familiar wireless communication, and battery systems. The weak points would be solved via recent techniques.

What kind of advantages do they have using the therapeutic robot technology compared to the traditional rehabilitative methods? First, rehabilitation robots are able to perform the therapeutic action repeatedly and continuously without any fear of tiredness [7]. Second, the therapeutic robots can provide the high level of therapeutic service on average. Third, the robots simultaneously evaluate persons during a treatment session [7]. Last, the robot may reduce the cost of rehabilitation service.

Therapeutic robots have following demerits. First, there exists uncertainty for safety of the disabled people. Second, specific robots are hard to perform various treatments like therapists. Third, therapists use to speak as well as move their hands and bodies in order to instruct the right posture and control of patients' movements. In addition, the clinical comparison researches on the effectiveness of the robotic therapy are strongly required.

Mechanical linkages such as a traditional keyboard, a mouse and a joystick have widely used for device control in conventional commercialized systems [8]. Finding reliable voluntary movement of a disabled person becomes a complicated problem.

Advances have been mainly made in interface technologies by means of biosignal. Various biosignals can help severe disabled persons to interact with device [9]: studies in infrared sensing, electromyography, oculography, and computer vision are in progress for those retaining some limited motor abilities. Besides, brain signals (electroencephalography, electrocorticography, etc.) have been investigated for those presenting as locked in. Biosignal analysis can be performed to understand a state of the measured person, e.g., emotion detection. Finally, feedback information that comes from a device has benefits. It can make the user aware of the system status and how well it is performing. It can help the control system to adjust to changing conditions.

3 Research and Development Pathway of Robots

The research and development of rehabilitative and assistive robots will be processed under the following philosophy. First of all, we will research and develop the practical systems that correspond with the physically disabled persons' requirement in the daily life. In order to focus on the consumers of those systems, we will survey the requirement of the disabled and collect the related experts' opinions. We will make surveys on the basis of International Classification of Functioning, Disability and Health (ICF) [10]. The questionnaire will be progressed for the disabled, medical experts, and engineering experts. Supporting employment for the disabled is one of important items as well.

Second, specific task-oriented rehabilitative and assistive systems for the disabled will be developed. The suitable combination of high and low technologies can construct practical systems. We will develop the system that has a basic functionality of activities of daily living. For example, we seem to develop a system that does not need the strong modification of the environment. After developing the basic function system, we will expand a system's function which has intelligent technology, i.e., a vision processing. We will not focus on the humanoid typed robots because theses systems are not easy to make a contribution for the disabled in near future.

Third, we will develop systems that should be useful for rehabilitative medicine. The cooperation between engineers and medical doctors will be performed in the early stage. In addition, the seamless clinical assessments must be continuously applied to overall R&D processes.

Fourth, the target market should be divided into two parts: domestic and international markets. Each country has her original style like eating habit and home structure. In case of Korea, they usually eat Korean styled soup. The most Korean houses are condominiums styled and the size of houses is a little small relatively. We will focus on the Korea styled living environments.

Finally, we will integrate various core technologies from multidisciplinary fields. A university or an institute that has various core technologies like a fuel cell battery could be one of good partners.

The R&D of rehabilitative robots gets started from simple devices with one degree-of-freedom in upper limbs on the basis of electrical actuators, e.g., DC motors, and/or pneumatic actuators. For example, major applicable areas are on the wrist and elbow joints for the stroke and spinal cord injuries. These systems can be applied toward uncomfortable direction of body movements. In addition, we will make possibility research of hand supporting systems.

Assistive robots can be separated into two ways: upper and lower bodies. A feeding supporting system can be the exemplary system in case of assisting an upper body. An eating assisting system could handle the Korean style soup. A wheelchair-based system which includes a compact robotic arm can simultaneously support the mobility and the manipulability based on helping a lower body. The size of systems should be compliable to the Korean body size.

A smart home with wireless technology could be another issue. Many autonomous systems are easy to develop and apply the real environment as environmental restrictions as possible. The robots can be successfully functional in the semi-structured surroundings.

4 Concluding Remarks

Research Institute of NRC in Korea will focus on developing practical rehabilitative and assistive robots with smart home environments on the basis of customer participation design concepts.

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A Predictive Analysis of the Night-Day Activities Level of Older Patient in a Health Smart Home

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Abstract. The present paper focuses on the experimental set up of a Health Smart Home (HSH) "or HIS in French" with presence infrared sensors (PIR) to detect and report data on the daily activities of fragile person in hospital suite. To study the data, predictive analyses are used to find the most pertinent parameters and indicators of these activities. A relationship is established between the activities of night (nocturnal) and day (diurnal).

Keywords: Health Smart Homes, activity monitoring, circadian rhythms.

1 Introduction

The fast increase of elderly population causes an international public health problem. The "Health Smart Home" [1] is the potential solution to maintain elderly people safely at home. Many researches have been done, with sensors and networks to detect the health and behaviour of occupants [2]. Most existing systems are based on presence sensors and door contacts which respects the home intimacy [3,4]. The major challenge is the early prediction of trends in the health status, so as to produce indicators for chronic diseases. This paper focuses on a field experimentation of a HSH, which adopts the (PIR) sensors to detect the daily activities of a fragile person. A predictive analysis is used to find the most pertinent parameters and indicators of these activities. One is the relationship between the activities at night and day.

2 Material and Methods

2.1 The Hospital Suite

The HIS (In French: "Habitat Intelligent pour la Santé") is a system based on the "HSH" concept [1]. It was built in our laboratory several years ago and actually under test in hospital suites [4]. This paper concerns the experimental set up, installed in a hospital suite [6], which consists of a main room, with bed and armchair, and a toilet. The (PIR) Sensors were placed on the walls (height 1,80m) so as to detect a presence on the bed, the armchair, at the bath sink, in the cabinet or at the main entrance door (Fig 1).

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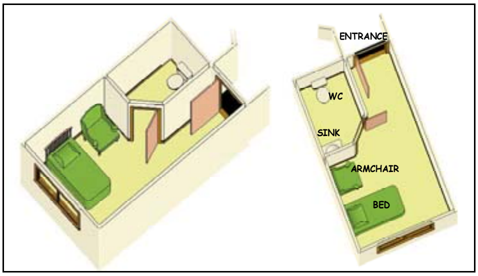

Fig. 1. The experimental set up is a Hospital suite with the 5 presence sensors

2.2 Data Processing

The data collected is stored as lines of time series to build a list of detection events [Date-Time-Localization] converted in a XML file, further transmitted once a day by Email to a central data base [2]. Upon reception, the file is loaded in the Matlab™ environment, and stored in a preliminary matrix of detection events. After transformation of data through a time discretization and rectangularization, we obtain the final form of the signal (1)

n=S*(j,i) with j ϵ [start day, end day], i ϵ [1,86400] : seconds, n ϵ [0,5] : 1 to 5 = sensor number	(1)

The visualization of signal $S_J*(i) = S*(j,i)$, the "ambulatogram" [6] shows immediately the localization and length of daily activities and occupations.

2.3 Parameters and Indicators

From this raw data several parameters were elaborated [5], such as: 1) the mean number of events for each sensor, 2) the number of diurnal events, 3) the total number of nocturnal events. The goal is to produce relevant indicators to point out the non visible abnormal trends of activities in the suite, so as to inform the health team, in charge of the patient. Therefore, we decided to focus on the following indicators: 1) the mean activities in front of each sensor (movements), 2) the mean displacements from one sensor to another (displacements), 3) the mean activity during the day (diurnal activity), 4) the mean activity at night time (nocturnal activity). After normalization (2), the data is in the same space [0…1], thus it is possible to proceed with data fusion techniques,

$Ind_i(j) = value_i(j)/ Max\{value_i\}$, with i = identifier of the indicator and j=day	(2)

3 Results

3.1 Experimentation

The data were collected during a 2 months period (May 21 to July 18th, 2007) on the hospital suite. The occupant was an elderly person aged 86.

3.2 Correlation of Data with Direct Observations

During the survey some information were reported by nurses and observable on the collected data, such as “bad sleep” or “faintness” (Fig. 2).

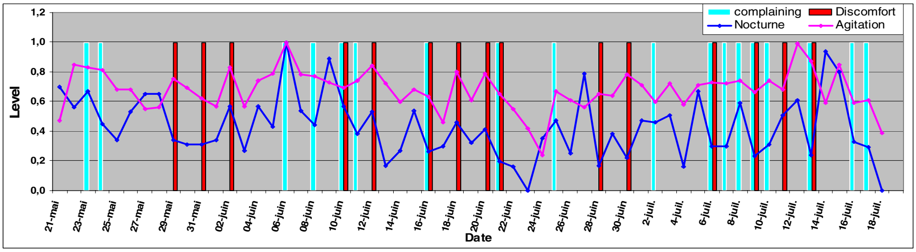

Fig. 2. Observations of real events on the activities level at daytime and nighttime

The following table shows the major points of the observations which often are confirmed by the coordination with the medical health record of patient:

Table 1. Correlations between the HIS observations and the health record

Date	HIS data observations	Medical health record
23-May	No observations.	Complaining, bothered by the clock noise.
24-May	High diurnal activity.	Complaining, felt not well.
29-May	Decline in nocturnal activity.	Discomfort, headache.
31-May	Decline in nocturnal activity.	Violent discomfort and pain in the hip.
02-June	No observations	Discomfort, hypertension.
06-June	Pick of both activities.	Complaining, worried for lack of medicine.
08-June	No observations.	Complaining, felt not well.
10-June	Activities values are close.	Discomfort, felt not well.
11-June	No observations	Complaining.
12-June	No observations.	Discomfort, cardiac problem and hypertension.
16-June	Decline in nocturnal activity.	Complaining, felt pain and hypertension.
18-June	High diurnal activity.	Discomfort, bad sleep.
20-June	No observations.	Discomfort.
21-June	Decline in nocturnal activity.	Discomfort, felt weak.
25-June	Activities values are close.	Complaining, felt weak.
28-June	Decline in nocturnal activity.	Discomfort and pain in the chest.
30-June	Decline in nocturnal activity.	Discomfort and hypertension.
02-July	No observations.	Complaining, pain in the feet.
06-July	Decline in nocturnal activity.	Discomfort, headache and hypertension.
07-July	No observations.	Complaining, headache.
08-July	No observations.	Complaining, felt weak.
09-July	Decline in nocturnal activity.	Discomfort, pain in the chest with agitation.
10-July	No observations.	Complaining.
11-July	Activities values are close.	Discomfort, hypertension.
13-July	Decline in nocturnal activity.	Discomfort, headache and pain in the feet.
16-July	No observations.	Complaining
17-July	Decline in nocturnal activity.	Pain in the right leg with hypertension feeling.

4 Conclusion

The daily activity at home can be monitored with simple PIR sensors placed in functional zones. Some indicators of activity are elaborated to build a vector of features. Actually, the process of interpretation is very difficult due to multiple and complex relationships between the level of activity, the health status and even more the self feelings of the person. Our approach of the correlation between night and day activities gives promising results on a preliminary experimentation. It aims at the automatic assessment of the daily activities of a person living independently in home.

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Spatiotemporal Data Acquisition Modalities for Smart Home Inhabitant Movement Behavioural Analysis

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Abstract. In current Smart Home implementations pressure sensors within the environment are normally deployed in a uniform pattern. Nevertheless, in order to create an optimised pressure sensor deployment paradigm it is necessary to correlate the positions of sensors with the high frequency movement behaviours of the inhabitant. The locations of furniture and other objects in the environment should also be taken into consideration. To create a paradigm for optimised sensor deployment, data pertaining to inhabitant movement behaviour first needs to be collected. This paper outlines the evaluation of two movement behaviour capture methods and assesses them for practical issues such as ease of installation and feasibility of use.

Keywords: Smart Homes, pressure sensors, virtual sensors, video analysis.

1 Introduction

Devices within a Smart Home can be used to effectively manage the safety and well-being of the inhabitant through the intelligent processing of activity data [1]. It has been shown that the accuracy of decision support systems within Smart Homes rely heavily on the information obtained from the sensors embedded within the environment [2]. The installation of some sensor types e.g. magnetic switches, require little evaluation as the goal of such a device is to detect a simple binary signal [3]. Nevertheless, the deployment of other types of sensors, such as pressure pads and passive infrared sensors (PIR) may require a greater level of consideration to achieve acquisition of the highest quality of data [2]. Currently data pertaining to inhabitant coordinates within a Smart Home's floor space can be acquired through the use of pressure pads which have been deployed in a homogeneous tiled formation covering the entire surface area of the environment which is being monitored [4]. This deployment technique does not account for the positions of objects (e.g. furniture) within the floor space. In reality this factor may result in one or more specific tiles either being used infrequently or never being used due to obstruction. The deployment of pressure sensors in such a homogeneous tiled formation also bears no correlation to the unique movement behaviours of an inhabitant with a Smart Home.

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It is the overall aim of our current work to create a novel optimisation paradigm for sensor distribution optimisation in Smart Homes. We expect to achieve this optimisation by processing data using methodologies such as object detection; pattern recognition, random search algorithms and genetic algorithms. Nevertheless, the first task in this process relates to the collection of spatiotemporal inhabitant movement behavioral data which can be used for object detection (the inhabitant) and pattern recognition (the inhabitant's movement path).

There are two techniques available to achieve the first stage of this process. Method 1 involves collecting data via non optimised pressure sensors whilst method 2 involves capturing data via a single camera using physical markers in the environment to in effect create 'virtual' sensors. The purpose of this paper is to test the hypothesis that the datasets derived from both techniques will either match or will be similar, and to assess factors surrounding the installation of each method.

2 Related Work

Pressure sensors within smart homes are normally deployed with the purpose of identifying an inhabitant's real time XY coordinates [5][6]. More rarely, however, are pressure sensors used in order to identify individual inhabitants from one another, or to gather data relating to an inhabitant's movement profile. Notable studies in this area include the work of Orr and Abowd [7]. Other research into user recognition via pressure sensors has been carried out by Addlesee *et al.* [4]. They used pressure sensors along with loadcells to measure ground reaction force (GRF) to identify individual users. Whilst these techniques have been shown to be accurate and useful, profiling an inhabitant and their movements using the pressure sensor methodology carries significant disadvantages including "privacy, cost, technical installation and retro-fits and practicability" [1]. The benefits of pressure sensors being installed in optimised positions in the long term outweigh these disadvantages; however it is hard to justify such disadvantages as high installation costs and permanent alterations to an inhabitant's home for short term empirical data capture.

West *et al.* [8] also noted that empirical data capture via sensors typically requires their deployments in large amounts [9]. This differentiation between the inanimate environment and single and multiple occupants within Smart Homes has also been the focus of much research conducted within the area of computer vision techniques [10].

3 Methods

We installed two prototype data capture methodologies in order to determine their accuracy and comparative cost. In addition we collected further data to support a qualitatively assessment of the experience of installation for both methods taking into account time taken to install and any associated difficulties. Both methodologies were deployed within a smart lab situated at the University of Ulster in Northern Ireland [11]. Method 1 involved the deployment of pressure sensors underneath a carpeted floor space within the smart lab. The pressure sensors were 1.5" thick polymer film manufactured by 'Interlink Electronics' [12].

Method 2 is similar in nature to the proposal of West *et al.* [8] to use 'Virtual Sensors'. We positioned a single lens camera (Logitech Quickcam v11.5) to the ceiling of the kitchen environment within our smart lab. The strip of pressure sensors from method 1 were labeled A1, A2...A6; whilst a corresponding strip of 'virtual sensors' from method 2 were labeled B1, B2...B6. A test subject was asked to walk the length of the room deployed with the pressure sensors and virtual sensors respectively.

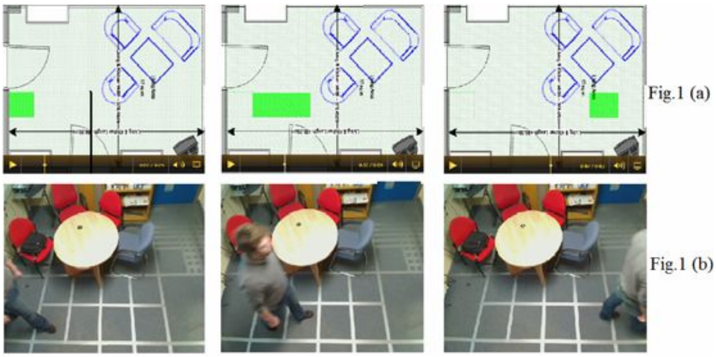

Fig. 1. (a) Method 1 pressure sensor set-up and (b) method 2 'virtual' pressure sensor set-up

4 Results

Figure 2(a) shows the presence detections obtained via method 1 using pressure sensors as the subject walked through the environment. Figure 2(b) shows presence detections obtained via method 2 using video capture analyses.

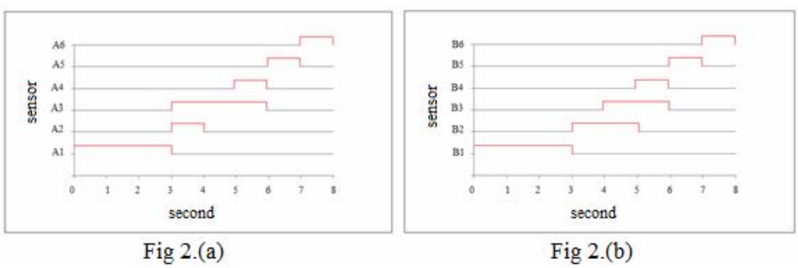

Fig. 2. (a) Method 1 pressure sensor detections and (b) method 2 'virtual' pressure sensor detections through video analysis

Whilst both data sets are not identical they do exhibit patterns of similarity. It is highlighted here that the only significant difference between the two datasets is the manner in which they were collected. The installation time for method 1 was 2.0 days. The installation time for method 2 was 0.5 days. Installation costs for method 1 and 2 were £50GBP and £20GBP, respectively. Both approaches had the ability to accurately capture the walk sequence of the subject within the test environment. Deployed sensors from method 1 required manually ad-hoc optimisation to avoid the occurrence of tile-tile interference. Permanent environmental alterations were required whilst installing method 1. Installation of method 2 did not require any major alterations to the sensing environment. Time spent on installation and costs were substantially lower using method 2, with no loss of accuracy.

5 Future Work

In this current work, one test subject was recorded and only two datasets were produced for comparison. Future work has been scheduled to include multiple test subjects. Ideally these subjects would be target cohorts e.g. dementia sufferers; however, as this may also be difficult, impossible or indeed unethical, the use of actors specially trained by psychiatric nurses or gerontologists' to exhibit common symptoms or behaviours may be a viable alternative. Indeed Mihailidis *et al.* [13] used a professional male actor in the development of the 'COACH prompting system'; an Activity of Daily Living (ADL) prompting tool.

With reference to method 2 of the current work the next step in our research will be the development of a system to automatically detect an inhabitant from the sensing environment using a fixed camera. There will be a number of stages to this next phase; first we intend to write an object detection algorithm that will have the ability to distinguish an inhabitant from streaming video data. This object detection technique would then be detection coupled with a tracking algorithm that will allow the movement patterns along the floor space of an inhabitant to be accumulated. The following phase from this would then entail the use of a random search algorithm progressing to a genetic algorithm to ascertain optimum sensor deployment coordinates specific to the inhabitant and their particular furniture arrangement.

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Towards Improved Information Quality: The Integration of Body Area Network Data within Electronic Health Records

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Abstract. An Electronic Health Record (EHR) is internationally recognised as the primary digital format to communicate and store patient clinical information. The vast majority of patient vital sign monitoring solutions provide limited if any opportunities to seamlessly integrate *real-time* patient vital sign readings e.g. ECG in a coherent or unified approach. In this paper, we highlight the data quality benefits of integrating remote patient monitoring solutions i.e. a Body Area Network (BAN) datasets within patient EHR solutions. The presented Data Management System-Tripartite Ontology Medical Reasoning Model (TOMRM) solution demonstrates how patient care may be improved through the reduction of false alarm generations.

Keywords: Electronic Health Records, Body Area Networks and Data Quality.

1 Introduction

An Electronic health record (EHR) is an integral element within health care services [1]. It provides caregivers with a recognised standard approach to communicate and store patient clinical information. EHR systems are designed to increase efficiency and promote higher levels of integration within our healthcare institutions. However EHR architectures provide limited capabilities to successfully integrate real-time patient vital sign monitoring devices. A patient monitoring device designed to output HL7 documents tend to be proprietary lead and are incompatible with neighbouring devices. The lack of complete integration between EHRs and BANs has major implications on the quality of data delivered to the medical practitioners, thus in turn it negatively affects the overall quality of patient care. The presented Data Management System-Tripartite Ontology Medical Reasoning Model (TOMRM) model [2] highlights how EHRs may be enhanced to realise their full potential through the integration of real-time patient vital-sign readings.

2 Evaluation

The DMS-TOMRM is evaluated based on its ability to accurately identify a patient's state of health through its ability to reduce the number of false alarm generations.

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Table 1. Generic Pulse Readings for Resting Patients or beats per minute (BPM)

Patient Type/ State	Low Criticality	Medium Criticality	High Criticality
Non-Athletic	65-95 BPM	60-74 BPM ‖ 96-100 BPM	<60 BPM >100 BPM
Athletic	55-65 BPM	50-54 BPM ‖ 66-70 BPM	<50 BPM > 70 BPM
Child	110-150 BPM	100-109 BPM ‖ 151-160 BPM	< 100 BPM > 160 BPM

Three patient types are identified 1) Non-Athletic Adult, 2) Athletic Adult and 3) Child (less then twelve months old, new born baby). The generic BPM range for each of these three patients in a resting state is presented in table 1.

Test Case Environment

The Medical Knowledge Base agent has access to Jade Content Ontology classes outlining generic pulse regions [2]. After evaluating the patient's BPM BAN readings, the DMS-TOMRM returns a Low, Medium or High patient risk type. These pulse regions are outlined in table 2.

Table 2. BPM Categories for Patients in a Resting State

Type	Meaning
Low (L)	Expected patient sensor reading
Medium (M)	Slightly outside the expected range
High (H)	Patient needs to be evaluated immediately

Experiment 1: User Profile and External Stimuli

If access to the medical knowledge base is not available (cf. fig 2) the real-time pulse sensor readings may be referenced against the patient profile. This will help to continually monitor the patient's state of health. Also as the patient type is identified the expected pulse range is narrowed. This will help to reduce potential false alarms.

Table 3. The use of a partial DMS-TOMRM model with User Profile and External Stimuli, examines different patient readings (i.e. BPM) under a specific set of scenarios

Patient Type/BPM	**35**	**45**	**50**	**56**	**88**	**95**	**125**	**150**	**180**
Child	H	H	H	H	H	**M**	**L**	**M**	H
Non-Athletic	H	H	**M**	**M**	**L**	H	H	H	H
Athletic	H	H	H	**M**	H	H	H	H	H

For a partial DMS-TOMRM configuration (cf. table 3) one high state was viewed as a medium when it is actually a high (Child, 95/BPM). Two high states were viewed as a medium and one medium state was viewed as a high (Non-Athletic, 95/BPM).

Finally one false alarm was incorrectly triggered when in fact it was a medium (Athletic). As the medical knowledge base was not available, a more precise pulse range was not defined. This resulted in three alarm triggers not activated and two false alarm conditions.

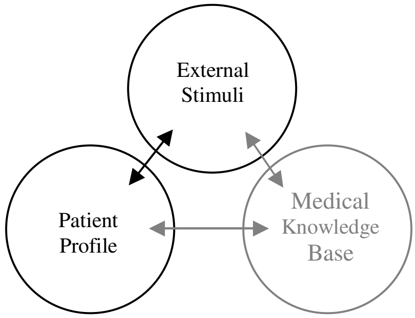

Fig. 2. Partial DMS-TOMRM, with Patient Profile and External Stimuli

When all information in relation to the patient's history, type (user profile), medical knowledge base (generic pulse regions) and real-time sensor pulse readings are available a complete picture of the patient's state of health in relation to their resting pulse rate may be achieved (cf. fig 3). In table 4 the results for this configuration is presented. All low, medium and high patient states were recognised correctly, resulting in no false alarms. This can help the medical practitioner to build up trust in the system. It also helps to improve the QoS as high risk alarms may be accurately raised when given the correct information. Experiments 1 and 2 were conducted in a controlled environment. Further analysis of the DMS-TOMRM is required within a natural environment to completely evaluate its turn capabilities.

Experiment 2: A Complete DMS-TOMRM Experiment

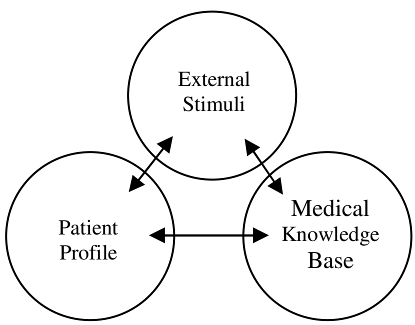

Fig. 3. A Complete DMS-TOMRM, with User Profile, External Stimuli and Medical Knowledge base

Table 4. A Complete DMS-TOMRM Model

Type/BPM	35	45	50	56	88	95	125	150	180
Child	H	H	H	H	H	H	**L**	**L**	H
Non-Athletic	H	H	H	H	**L**	**L**	H	H	H
Athletic	H	H	**M**	**L**	H	H	H	H	H

3 Conclusion

Presented is the Data Management System-Tripartite Ontology Medical Reasoning Model (DMS-TOMRM). This novel approach is designed to assist medical practitioners in providing a higher quality of patient care within a pervasive medical environment. It correlates all known static and dynamic data sources e.g. BAN and EHR to assist medical practitioners during patient diagnosis. The DMS-TOMRM component gathers and correlates all known information from numerous sources including EHRs, BANs and external sources. From here it is able to evaluate the patient’s state of health and provide valuable data to the medical practitioner at the patient point of care, which is a distinct advantage over current disjointed data gathering approaches [3], which may be found in the majority of our medical environments.

As highlighted in [4] not every single data element captured by the BAN needs to be transmitted to the medical server for analysis, predefined ranges may be set by the medical practitioner to meet the individual needs of the patient. The major obstacle to widespread usage of models similar to DMS-TOMRM stem from the proprietary BAN devices and standards. This forces medical institutes to purchase incompatible medical devices which in turn may not comply with HL7 standards, thus undermining their original design philosophy.

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Distributed Dynamic Self-adaptation of Data Management in Telemedicine Applications

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Abstract. In telemedicine, patient data have to be shared among mobile and geographically dispersed caregivers. The execution environment of telemedicine applications is characterized by hardware and software heterogeneity and can suffer from important variations in resource availability. The data replication can be used to provide significant benefits in terms of data availability and query latency. Moreover, the replication system has to be adaptable to changes of context for a high quality of service. We establish two architectural models, one for distributed replication systems and the other for distributed adaptation systems. We are currently implementing them as two frameworks that can be customized to build an adaptive replication system for a telemedicine application.

Keywords: Software architecture, Distributed dynamic adaptation, Data replication, Telemedicine.

1 Introduction

Telemedicine applications can provide remote health care to patients and ensure collaboration between caregivers at distant sites using communication facilities. The execution environment of such applications is characterized by a wide diversity of caregivers' hardware (e.g. PC, PDA) with wired or wireless connection and by dynamic network variations (e.g. bandwidth). Moreover, caregivers need customized services to meet their different requirements. Patient data like monitored vital signs and laboratory tests have to be shared among health providers to ensure effective care. The distribution of telemedicine applications and their users over vast distances requires a distributed replication system to ensure data access to be performed with reasonable query latency and reliability.

The replication system needs to be adaptable because of the dynamicity of the context in which it is run and the broad range of users' requirements. For instance, it should adapt to unpredictable disconnections that may occur when a doctor with a mobile terminal moves outside network boundaries. Due to the distributed nature of replication systems, existing centralized adaptation

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architectures are not enough to make them adaptive. Therefore, we propose a model for distributed dynamic adaptation that can be derived in order to build a concrete adaptation system.

We have worked on applying our adaptation model and the derivation process on data replication systems in order for them to be adaptive. We have considered a telemedicine application that integrates several services: the telediagnosis and the teleassistance of a patient with a chronic disease and the teleconsulting among distant caregivers. A system for monitoring the patient at home tracks his vital signs. For these services, a data management system handles patient data stored in distributed patient health records. A replication system replicates these data.

The paper is organized as follows. In Section 2, we propose our framework for the development of distributed replication systems. Section 3 presents our framework to support distributed adaptation. Finally, the last section concludes this paper.

2 A Distributed Data Replication System

We have defined a distributed replication system as a derivation of an architectural model that offers four main functionalities. *Replicas placement* creates/deletes replicas and places them on nodes that we call sites. *Replicas selection* is responsible for the choice of the replica(s) to be accessed by the client application. *Replicas access* functionality manages the local access to replicas. Accesses may concern reads or writes from clients or updates from other replicas. *Updates propagation* ensures the control of replicas' modifications and the propagation of updates among them. Together, access and updates propagation functionalities ensure the consistency protocol by executing clients' operations and the mutual consistency of copies. We have implemented this model as a component-based framework. A software component is a unit of composition with contractually specified interfaces and explicit context dependencies only [1].

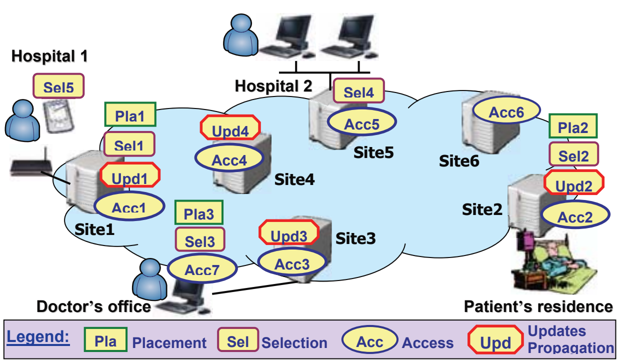

Fig. 1. The replication system of the telemedicine application

A family of replication variants can be derived from our framework. A derivation process has to be applied on the architectural model in order to build a concrete replication system. Figure 1 shows a variant for the telemedicine application. We consider the case when data are accessed by a pulmonologist in his office, a nurse in a nearby hospital and a cardiologist in another faraway hospital. The developer of a replication system uses a derivation module to specify the application architecture (consisting of components, connexions and hosts). In addition, he customizes the behaviour of components. For example, he chooses a random placement algorithm for placement components. The selection components find the replica on the site corresponding to the least number of hops from the requesting client. Weak consistency protocol (copies are allowed to diverge temporary) is chosen. The derivation module deploys automatically the system.

3 Our Software Architecture for Distributed Adaptation

In this section, we present our architectural model for distributed adaptation implemented as a component-based framework.

To implement adaptability, a component (composite and/or distributed) is associated with a primitive adaptation system. This system offers four main functionalities: monitoring, decision, planning and execution [2]. A *monitor* manages the context by a subscribe/notification mechanism. The detection of any relevant change in context triggers the notification of the *decider* of the concerned component which chooses the best adaptation strategy by interpreting an adaptation policy. The strategy is received by the *planner* which schedules the actions implementing the decided strategy into a plan. Finally, the *executor* executes the planned actions.

Several primitive adaptation systems can be used to adapt distributed application components, each being responsible for adapting a subset of components. Such a decentralized approach can reduce problems related to the complexity of system customization (e.g. policy specification). Moreover, distributed adaptation can avoid the adaptation overload, the failure of the system and the limitations on scalability. However, cooperation may be necessary to make collective decision or to build and execute coordinated plans. For that, deciders, planners and executors should integrate the appropriate components for cooperation. The main objective is to maximize combined benefit of all application components and ensure the global consistency of application.

An adaptation expert derives the appropriate adaptation system to associate it with his replication system. The process is similar to the replication system derivation. For our application presented on Figure 1, the expert derives a distributed adaptation system. For example, he can instantiate several monitors since the environment is heterogeneous. Each one manages specific network domain (hospital 1, doctor's office, etc). Several deciders can also be deployed especially because the application components can have different adaptation policies. The replication system becomes self-adaptive. For instance, when an emergency occurs, parallel adaptation processes are started in order to reduce query latency and increase the availability and the consistency level of data. In one of the processes, the deciders associated with the updates propagation components negotiate the best consistency protocol according the global context and choose strong consistency (updates are immediately propagated to all copies).

4 Related Work

Existing works [3,4] provide dynamic adaptation of some functionalities of replication systems. However, adaptation mechanisms are embedded on the application and are often highly specific to it. This makes it hard to modify and extend the adaptation system and to reuse it across different replication systems.

Several approaches [2,5] have been proposed to target adaptability in general. They propose self-adaptive component models by managing adaptation as a separated concern from the application functionalities. However, adaptation in these approaches is centralized. The distributed nature of applications and the highly heterogeneity of their context have not been sufficiently considered. Our approach supports dynamic and distributed self-adaptation and introduces a method for distributed adaptable systems derivation.

5 Conclusion

In this paper, we have described a new framework for the development of distributed adaptation. We have illustrated our approach by specializing our adaptation model to make a replication system of a telemedicine application adaptable. We have chosen the Fractal model [6] as the underlying component model implementation as it is modular and extensible. We have begun implementing an adaptive replication system for the telemedicine application based on our two frameworks. However, the current prototype should be extended to cover more advanced cooperation mechanisms. This will be a topic for our future research.

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