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Lifestyle Monitoring System to Improve the Well-being of the Elderly

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Abstract: The size of the ageing population is growing fast because people are living longer and environmental and social conditions are changing. This paper will report a study to design and develop a technological solution that helps to improve the independence and well-being of the elderly. We initially read some literature about telecare, lifestyle monitoring systems, well-being, smart-houses, and pervasive computing; topics which are all relevant for our research project. We then started to understand the data gathered from the array of sensors collected into a database in order to present useful information to the end user through OnLine Analytical Processing (OLAP). In the second stage, we will analyse the information required to find rules, patterning sequences, which reveal hidden data and will enable us to predict changes using data mining techniques.

1 INTRODUCTION

Given that people are living longer, ageing society is increasingly quickly. Many European, American and Far Easter countries are starting to face crisis because there are not enough resources to support either medical or social services that this population needs. The big challenges are to help older people to stay healthy and active, to encourage their independence, and to support their well-being with the help of technology.

Many researchers are already using telecare systems to explore the issues associated with technology that supports home living but most of them are focusing on monitoring the daily activities of the elderly such as how often the elderly take showers; which might seem a bit intrusive from an ethical point of view. During the last five years, an important number of projects have been undertaken in the UK such as The Care in the Community Centre, whose aim is to monitor changes relating to the well-being of elderly people and to provide relevant information to formal and informal carers [Brown, Hine, Sixsmith and Garner (2004)].

According to the conceptual model of personal well-being [Brown et al. (2004)], it is associated with personal factors such as physical and psychological attributes; context factors such as security at home, and the presence of social networks and social support; the kind of activities done by the person within the home, daily living, leisure activities and social life, and the way that the person perceives his life. The final product is the measure of well-being in terms of physical, mental and social aspects.

The earliest studies of providing care to the elderly at home were done in 1981 in the UK. These were concerned with both ergonomic aspects of alarm devices and their technical efficiency [Fisk (2003)].

There was another experiment made in Scotland of social alarms, where the service helps a group of 12 elderly people. Sensors were installed in the houses with the aim of monitoring activities. Each house was connected to a central monitoring centre where a person attended the emergencies.

One of the pioneering telehealth research projects was conducted at the University of New South Wales, Australia. The projects of the university stated that it is possible to determine functional health status using remote monitoring systems and they were interested in finding the association between health status functions and changes to determine level of well-being [Celler, Earnshaw, Ilsar, Betbeder-Matibet, Harris, Clark, Hesketh and Lovell (1995)].

In 1998, the consortium British Telecom and Anchor Trust developed a prototype of a LMS in 22 houses in Newcastle, which was capable of monitoring peoples' movement through a sensor network and looking for deviations from a 'normal' pattern of behaviour that may indicate a potential problem [Porteus and Brownsell (2000)]. The aim of the project was to increase the independence of elderly people and reduce the period in hospital. It also helped to increase peace of mind both for the elderly and for the family.

Various research studies has been undertaken in the USA such as the Aware Home carried out by the Georgia Institute of Technology [Mynatt, Rowan, Jacobs and

Craighill (2002)], whose aim was to improve the quality of life of elderly people. This project is innovative using a digital portrait as an interface to keep an open channel of communication between parents and children, and to show the activity level of the resident through butterfly icons that change their size according to the level of activity.

A multidisciplinary team of researchers from the Massachusetts Institute of Technology (MIT) developed a project called Changing Places/House_n [Intille (2002)], whose purpose was to create pervasive computing environments for the home. They are developing technologies and designing strategies that use context-aware sensing to empower people with information by presenting it at the right time and place.

In the University of Texas at Arlington, a project called the Managing an Intelligent Versatile Home (MavHome) was implemented [Cook, Youngblood, Heierman-III, Gopalratnam, Rao, Litvin and Khawaja (2003)], whose goal was to maximise inhabitant comfort through the automation of tasks at home such as opening the curtains, lighting and heating; avoiding the control of manual appliances.

The University of Virginia [Alwan, Leachtenauer, Dalal, Kell, Turner, Mack, and Felder (2005)] established a Smart House project to evaluate a remote monitoring system. The team used several data analysis techniques, including clustering, mixture models [Barger, Brown and Alwan (2005)] and rule-based approach [Dalal, Alwan, Seifrafi, Kell and Brown (2005)], where sensor firing events were explored to infer specific activities. The study stated that a remote monitoring system with inexpensive motion sensors, can be used to detect patterns of behaviour.

The Gator-Tech Smart House project [Helal, Mann, El-Zabadani, King, Kaddoura and Jansen (2005)], carried out by the University of Florida, was focused on pervasive computing systems. The objective of this research was to increase the independence and quality of life of the elderly and the disabled.

Porteus y Brown Sell stated that a LMS, is specifically concerned with the use of technologies to help elderly and disabled people to live independently [Porteus and Brownsell (2000)].

2 HYPOTHESIS

Our study, therefore, is working within the following hypothesis: there are some patterns of behaviour such as sleeping, eating, social life, and exercising, associated with well-being. Analysing modifications in these patterns can predict future changes in health. Therefore, a person's activity level may reflect patterns of behaviour that can be measured using a Lifestyle Monitoring System (LMS).

3 OBJECTIVE

In order to explore the hypothesis, the study is focus on designing and developing a lifestyle monitoring solution that helps to support the independence and well-being of the elderly and allow them to live in their own homes for longer.

The following are specific objectives:

- To design a remote monitoring system based on sensors to record every movements of the occupant inside the house in a database.
- To measure the activity level of the elderly person in order to find out about their habits and patterns of behaviour that relate to their well-being.
- To provide information that could be useful to the users such as clients, relatives, formal and informal carers, etc.
- To analyse modifications in activity level in order to predict changes in well-being.
- To design qualitative methods in order to find out about the habits and behaviour of the elderly.
- To validate the effectiveness of the system and the accuracy of the results.
- To follow privacy and confidentiality policies.

4 RESEARCH DESIGN

The telecare system that we are developing to explore these issues consists of the following components:

4.1 Telecare

Telecare can be defined as a service bringing health and social care directly to a user in their own home, supported by Information and Communication Technology (ICT) [Hine, Judson, Ashraf, Arnott, Sixsmith, Brown and Garner (2005)]. It provides safety and security monitoring, physiological and activity monitoring information.

There are three generation of telecare. The first generation requires a client to manually raise an alarm for help in an emergency [Doughty, Cameron and Garner (1996)]. The second one incorporates a degree of intelligence that enables the system to alert a carer without the client's intervention. This is a useful feature in the event that the client is not able to raise alarms by himself. It uses an array of sensors to continuously monitor the client, the system interpret the current situation and automatically raise alarms when possible problems are observed. The third generation is able to predict events

and acts proactively to avoid chronic situations becoming acute. Based on the lifestyle monitoring and real-time analysis of activity it will facilitate an interactive communication between client and carer with the aim of visualise physical, mental and social issues related with the individual well-being [Brown et al. (2004)].

4.2 Sensor networks

Sensors networks are a set of devices mainly used to register peoples' movement, physiological conditions and environmental measures. The linking of different sensors to facilitate care of older and disabled people started with the second telecare generation, which offered the possibility to monitor individual well-being and raise alarms automatically to a central service where somebody was able to help.

There is a great variety of sensors to care people at home such us PIR (passive infrared sensor), smoke detectors, flood detector, occupation, health functions, but most of them work independently. The purpose is to determine the type of sensors and the suitable location to gather relevant information in order to analyse peoples' busyness. For our study we are using PIR, vibration, power, flood detector, infrared, light, switch and cooking sensors.

4.3 Lifestyle monitoring systems (LMS)

Lifestyle monitoring is linked with gathering information about individual activities and movements, as well as environmental conditions (temperature, humidity) and intruder alarms [Fisk (2003)].

Some benefits obtained from lifestyle monitoring are the ability to request help in the event of an emergency where someone remains unconscious; the reduction of false alarms redound to decrease of medical services. Lifestyle monitoring can assist in identifying and understanding the reason for calls, it means that following the log file it is possible to determine which sensor generated the issue and infer what the problem might be and the appropriate response.

4.4 Online analytical processing (OLAP)

OLAP technology allows the exploration and manipulation of huge volumes of data [Seidman (2001)], the visualisation of patterns and phenomena, the definition of dimensions and measures such as location and time and the selection of granularity level (day, week, month, etc).

OLAP is very useful in the financial sector for observing sales, profit and other business indicators, however, it is not well-known in the care and medical sector.

4.5 Data mining

Data mining is the process of discover useful and unexpected information in large datasets. It is based on the application of statistical methods, data classification, clustering, association and the combination of different techniques to generate interesting data for the end user [Seidman (2001)].

There are essentially two types of data mining algorithms predictive and descriptive. The predictive model uses the historical information to predict unknown values; the descriptive model find association and patterns among data to show hidden information. Depending the goal of the project the most suitable data mining technique is selected.

5 RESEARCH METHODS AND METHODOLOGY

According to previous research projects cited above is really appropriate to use quantitative and qualitative research methods in this work. The following is the proposed methodology to develop this project:

Collection of requirements With the aim of defining client requirements case scenarios are used to know the individual behaviour and aspects such as social life, fears, life satisfaction and physical conditions; which should be analysed through qualitative methods for example interviews, focus groups and ethnography.

On the other hand to validate the effectiveness, security and simplicity of the system and the confidentiality and accuracy of the results is necessary to design quantitative methods such as questionnaires and statistical study.

Installation of sensor within the home Houses with high probability to produce the interesting lifestyle patterns and anomalies are selected. In order to guarantee the success of the project, the person must agree to be monitoring.

Data Transmission The information gathered by the sensors is stored on line into a database, and we then this data is transformed into a data-ware house.

Data Visualization OLAP is used to visualise the individual activity level. Proclarity is the tool used to allow the end user to manipulate the information and show the data granularity level like week, day, hour, etc.

Data Analysis After understanding the data is necessary to find rules and patterns and to train the data mining model. The system then will compare the trained model with the data collected on-line; in the

event that a significant change is detected the application will be able to show the possible causes of deviation and will send this information to the appropriate person to follow the situation.

Feedback At this stage the system is evaluated in terms of advantages and disadvantages, level of acceptance from users such us client, formal and informal carers and modification will be made when necessary.

6 RESULTS

A partial database from the Care in the Community project was used to analyse the patterns of movement of the elderly people. PIRs, switches, flood and vibration sensors were installed into the house and were connected to an Input/Output (I/O) device to collect the information.

Then data was stored into a database and transformed into a data-ware house. The next step was to construct a data cube and defined dimensions, measures and levels of granularity. In order to understand the data Proclaritiy, which is a tool to visualise data, was used to draw the daily busyness level during 22 weeks. Each graph were analysed in order to find rules between days and locations and to discover patterns within the data. It was also possible to find sequences of data, which have space in time and location and volumes of activity at a certain time at a certain place.

6.1 What is busyness?

Busyness is the general level of activity of anybody within the dwelling. Whoever is in the house is contributing to registered activity, but for this study is not relevant to know who is being busy and what is being done. For instance, visitors and carers also contribute to the general busyness level.

Figure 1 shows how one day might look. There is some activity during the sleeping time, then there is a peak during breakfast time.

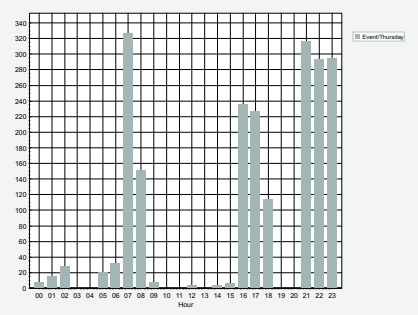

Figura 1: Daily busyness

At lunch time there is no activity, indicating that the occupant is not at home. Then there is lot of activity during tea time and late evening.

Based on the graph a carer might raise the following question: Does this person have an active social life? One of the answers could be: Yes, this person went to visit some friends; or No, this person remained in bed because of illness.

Daily activity from Thursday to Friday during 2 weeks can be observed in the Figure 2. It is possible to see changes between different days. For example, on Thursdays there is lack of activity during lunch time, but Fridays usually have activity during lunch time.

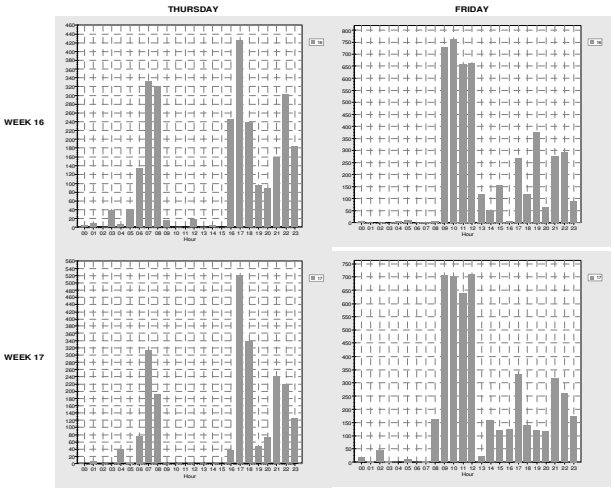

Figura 2: Daily busyness (Thursdays and Fridays)

Using Proclarity an end user can drill into the data and draw the daily activity. In order to see the activity generated by each room at an specific day, the sensor dimension was define as the x axis and the day dimension as the y axis. The figure 3 shows that there is huge activity generated in the lounge follow by the kitchen on Thursday.

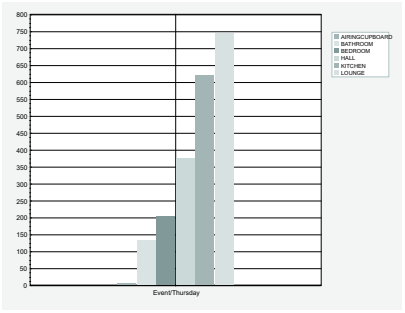

Figura 3: Daily busyness by room

It is also possible to use OLAP to compare the activity with other days or other weeks to see how activity

level changes by rooms over the time.

Drilling into the lounge activity level and look at how activity changed by hour, it is possible to observe that there is some activity in the morning, there is lack of activity from 9 to 15., there is a little increase during the late afternoon and there is quite more activity during the late evening between 9 to 11 p.m. The results are shown in Figure 4.

In this way, OLAP can be used to visualize data easily and quickly, which is a real advantage in comparison with other tools. In addition, from the dialogue of care point of view OLAP is a powerful tool that provides information to the carers and clients, to discuss and find out about the changes and patterns of the activity registered. The key point is to discuss any change of the information with the client.

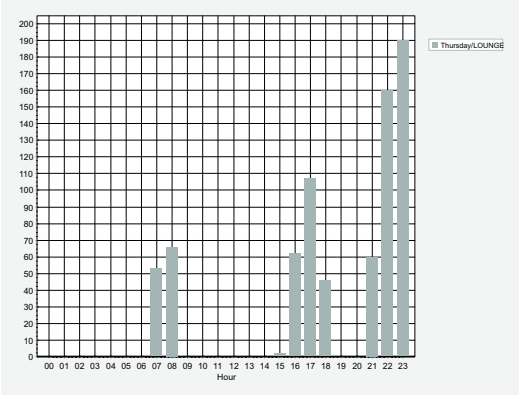

Figura 4: Hourly busyness in the lounge

7 NEXT STEPS

Based on the graphs showed in the last section the next step is look for rules and to discover patterns:

- Patterns of movement between places: For example a pattern between kitchen activity and living room activity and bathroom activity that happens at lunch time.
- Patterns of time: To know how the patterns fluctuates, how regular is the patterns, for example to have a meal sometimes it takes 10 minutes others takes half an hour but it is still a meal, how long does the client spend in the dwelling.
- Rules to recognize normal activity levels: It is normal for there to be no activity in the lounge on Friday lunch times. So when activity is detected at this time it suggest non-normal behavior, which should possibly be discussed with a carer as part of a "dialogue of care".

The second stage of this study is to find out about the correlation of repetitive or similar patterns; to analyze the data using data mining techniques to predict future changes that would be related with the individual well-being. At that point it would be possible to show more abstract data, data that is more difficult to visualize, or hidden data.

8 CONCLUSIONS

The aim of a LMS is to monitor and measure patterns of behavior associated with well-being of the elderly. These patterns can be measured through different tools and their changes can be predicted using data mining techniques. The purpose of this paper is to show how the data gathering from an array of sensors may help us to understand the behavior of the resident through OLAP.

OLAP seems to be a practical and easy tool to visualize information because it permits the end user to aggregate and drill down into the data at different stages. After this step will be very useful to segment the data and construct new cubes to analyst small pieces of information to know patterns in the data. This process should be an iterative cycle in order to discover hidden data.

Then we can data mine these patterns and visualize sequences of events, rules, fluctuations and volume of data; and analyze the correlation of repetitive movements that helps us to predict future changes.

We think that OLAP could be used to promote the dialogue of care between clients and their carers because the end user can define and visualize in an easy and fast way dimensions and the granularity level that he/she wants to see to detect and analyse issues related with the individual well-being.

We are focus on analysing the busyness activity rather than understanding the Activity of Daily Living (ADL) because we think it may provide enough information to know the lifestyle and patterns of behaviour of the elderly without disturbing their privacy.

To summarize, the integration of different tools and techniques such as data bases, OLAP, data cubes, segmentation and data mining are very useful to understand, analyze and visualise the data and predict future changes in the well-being of older people.

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