

Pervasive Healthcare in Smart Homes

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ABSTRACT

With the aging of the population the human resources and necessary space to provide adequate healthcare becomes a problem. It is increasingly necessary to find ways for the elderly and chronically ill to continue to have an independent life and, at the same time, it is also necessary to maintain constant vigilance. To overcome this problem it is necessary to change the current paradigm in healthcare system. One possible solution is the use of smart homes that allow patients to have a better quality of life due to the fact that this is a familiar environment. In this article we define what are the necessary requirements for a pervasive healthcare smart home. After defining the requirements we describe two systems for smart homes. Finally these two systems are evaluated according to the requirements presented previously and some improvements in both systems are made.

Keywords

Altcare, Smart Condo, Pervasive Healthcare, Requirements, Smart Homes

INTRODUCTION

Population growth and its aging is a problem for most healthcare systems due to various factors such as lack of human resources to provide necessary medical care, the increase in chronic diseases which require a constant monitoring and high costs to provide medical care. Only in U.S., medical care costs for chronic conditions like arthritis, asthma, cancer, diabetes and heart diseases are about 75% [2]. Using Australia, European Union, Japan and the United States as an example in 2007 was the percentage of people over 65 years old and above is around 13% to 21% of the population and taking into account the current trends of mortality and fertility in 2050 this number will grow from 20% to 36%. However this increase is not the most worrying factor, only in Australia the number of elderly is 2.75 million (13%) and more than half of the

people in this group suffer at least from one chronic disease [1]. As a result of this growth in the number of patients, the available space for the treatments becomes an increasing problem to which not all healthcare systems have the means to respond. The solution is to change the model of healthcare. Rather than take care of patients in one central place, distribute this care for several places. The best way to achieve this objective would be to use the patient's own home as a large hospital room where all the monitoring and support are given to the patient in his/her own home environment.

In this article we wish to understand what are the requirements needed to build a smart home to support the monitoring and care for chronically ill or recovering patients. Then we describe two systems of smart homes, the Altcare [3] and Smart Condo [4]. After a description of both systems, we will make an assessment in accordance with the requirements described earlier. Finally we will present some possible improvements in both systems.

REQUIREMENTS

In this section our goal is to find out which are the requirements for a home care's system. A system of home care uses technologies such as sensors, cameras, displays, data transmission, networks, etc. These systems may have two approaches, one supported on users and other autonomous. In the first approach the system depends on the direct interaction of the user to collect data. In the second approach the systems operates completely autonomously without user intervention. This type of system is mainly to be used by the elderly people or by people with mobility difficulties. To develop this kind of service we need to take into account the patient's freedom and the privacy of the data. We have to understand that an house is generally an harmonious space created over the years by the people who live there. With this in mind the systems have to be in accordance with the existing environments and be adaptable. The home support systems

usually focus on current patient's problems, not taking into account the problems that can arise over the years, and that over the time the ability of a person to engage in mundane activities can decline, these activities are called "*instrumental of daily living*". For this kind of systems the concept of "*embedded assessment*"[7] was created. This concept means that data is collected and analyzed for the purpose of detecting diseases related with aging in an early stage. Such systems can not consider only a single person in the process, but an extended network of people, whether they are people who care or who are cared for (doctors, nurses, patients) and also for people that are interested in the same information such as family members. Sometimes this kind of system is not operated in a house if there is only one resident. An example is that if a patient is giving information on a television, they may be other people to see that information but the patient does not want to share this. So the system's development must overcome some obstacles, not only with patients but also with all those involved, some of the requirements that must be met are:

Adaptability

The ability to adapt to the environment at home as well as the adaptation according to the stakeholders is the first requirement. This requirement is related with the system's ability of adding, removing and configuring components according with the user needs along the time. To be adaptable the system should be designed with the participation of multiple stakeholders like doctors, nurses, the patient and his family. To achieve this there are several problems in the design and requirements' process [5]:

- *Stakeholders have different perspectives and objectives and each one wants different things from the system.*
- *Stakeholders have different backgrounds and this can be a problem when they try to communicate.*
- *Stakeholders have different involvements in the system, the patient just wants the system to help him in the daily tasks and caregivers want the system to be able to monitor the patient.*

Teamwork

The second requirement is teamwork as if we want a monitoring system that is accurate and reliable we should introduce the user in the loop. If we have a system making all the decisions for us and at some point those decisions are wrong the user should be able to communicate with the system and notify that the decision that the system made was not the correct one. Also when the system is not able to make a decision based on the information available, the system should ask the user for additional information and

thus learn and adapt according to the environment. A successful smart home for pervasive healthcare should allow human-computer teamwork according with the following criteria [6]:

- *The user should be able to provide as much or as little initiative in the teamwork as they wish or are able to.*
- *The system should describe a user's digital persona, which should define how a user wishes to interact with other digital entities in differing digital territories.*
- *The system should be mobile and be able to control different pervasive environments to the same effect wherever possible based on the user's digital persona.*

Acceptability

The stakeholders should accept the system and feel comfortable using it. This includes system characteristics like usability, learnability, affordance, compatibility, efficiency, responsiveness and aesthetics [9] challenges.

Security and Privacy

This is a very important requirement because the data used by the system may be personal. Also when designing a smart home the most probable way to connect all the components in the house is by some kind of wireless network, and this kind of networks are more vulnerable to security issues. The use of video, audio or biometric information can increase a patient quality of life, but this can also represent a privacy issue if this information is unprotected from possible abuses [9].

Trustworthiness

The users should feel safe when using a smart home, a system misuse, a software bug, a hardware malfunction or interference in communication must be avoided. If the user has the ability to perform actions or to give commands to the system the misuse of some commands may cause problems to the user and be harmful. Also the malfunction of domotic systems could lead to damages to the house or to the neighborhood. Smart homes must ensure that safety of the users and the equipment's is a priority, and designers should avoid bugs and malfunction by creating mechanisms that could handle these situations if they happen. [9].

Ambient intelligence

The ability to collect information and use that information to make decisions is an important requirement. This includes areas such as data mining and machine learning.

An intelligent ambient should be unobtrusive, personalized, adaptive and anticipatory [9]. The automation of daily activities is an important aspect if the patient suffers from dementia and is unable to move around the house. Information about effort, accuracy and errors can provide early indicators of problems and increase the awareness for the patient or his family providing crucial medical information to be analyzed by the caregivers. Some design recommendations for ambient intelligence are [7]:

- *Provide appropriate representations of data to different stakeholders to support awareness.*
- *Support data-driven inquiry with the user.*
- *Codify data into scales with critical values to quantify significance in the data.*
- *Include rich model of the user actions to accommodate acceptable deviations from established routines.*

Healthcare systems at home must support the change. A common problem is that there is no standardization of data, therefore the person who is responsible for prescribing the treatment could not be able to use the data collected by the system to do a better job. If a doctor wants to share data with a colleague and they don't share the same system this could be difficult. For privacy problems, the concept of "bubble" was defined [6], this new concept means that we can create a distinctive ambience where only those who have authorization can access the data. This concept serves as a protection which only gives access to the ones who are authorized by the owner of the bubble thus all data entering the bubble is checked.

ALTCARE

Altcare [3] is the first application which we will evaluate. This application has the ability to learn the daily events of a person and the location of them using a network of cameras with wide angle lenses. Through this learning, the system detects emergency situations and tries to confirm whether it is an emergency situation, or not, communicating with the elderly person. If there's no response the system automatically contacts the person responsible for the patient and also makes an emergency call. This system uses a video technology called "masked video", which only shows the silhouette of the person. Another feature provided by the system is that at any time the family or the doctor can check the patient's condition and thus provide a more comfortable and safe living to the elderly.

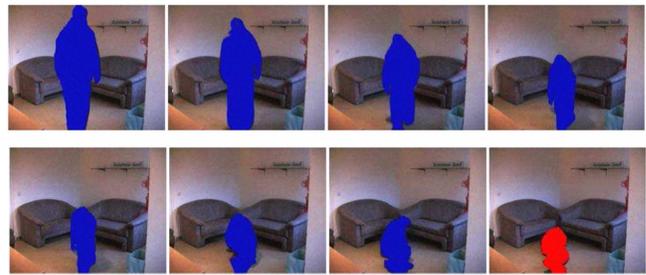


Fig . 1- Altcare fall detection.

SMART CONDO

The second application that we will study is Smart Condo [4]. This system of homecare exceeds several obstacles that are constant in smart homes for healthcare applications. The first aspect is the privacy of individuals, although it is known that this kind of service aims to facilitate medical care at home, the patients continue to have a certain resistance to abdicate their privacy. This system does not have any type of recording, sound or video, the system works with infrared for environment location and sensors on the seats to know if the person is sitting or not. Another difficulty is the variation of the conditions of the patient, in which the system must keep up with the improvements or relapses of each patient, which change constantly over time, adapting each situation through the sensors. This system provides all the information through two ways, a collection of data through sensor that can provide a 2D image or 3D environment. The data generated by the sensors is stored in a proper database that can be viewed by the patient's responsible.



Fig . 2 – Smart Condo 3D environment.

EVALUATION

In this section we will make an assessment of the systems Altcare [3] and Smart Condo[4] in accordance with the requirements defined at the beginning of this article. We will start with the Altcare system followed by the Smart Condo.

The Altcare system meets the requirement of adaptability as many cameras can be placed in various places inside the house. The requirement of teamwork is also fulfilled since the system allows the elderly person to press a button and inform the system if it was a false alarm before sending the request for help. Acceptance by patients is also fulfilled since the authors did a survey where they found that over 50% of the inquired would have no problem in using the Altcare system. The issue of privacy is fulfilled since the Altcare system has a masked video that ensures the patient privacy. Regarding the security issue, we consider that this requirement is not fulfilled, since that in the architecture presented the data is transmitted over the Internet. Since the authors did not mention security protocols or encryption algorithms we assume that they are not used in this system. The trustworthiness requirement is also fulfilled since the only components that can have bugs or malfunctions are the cameras, we consider that these do not present a danger to the patient. Finally, the requirement of ambience intelligence is also fulfilled since the Altcare have an algorithm that learns the patterns of the person over time.

With regard to the Smart Condo system the requirement of adaptability is fulfilled since the system is flexible on the types of sensors that support it. The requirement of teamwork is also accomplished due to the interaction between patient and doctor through a feature offered by Smart Condo that allows the patient to talk with the doctor via text or voice. Concerning the requirement of acceptance there are no data provided that shows whether patients will accept to use this system or not. Although a study shows that around 50% of the patients are willing to use a smart home [8]. Regarding the privacy issue we consider that this requirement is fulfilled since the only images that are transmitted are the images of an avatar of the person. In relation to security we consider that there may be some problems due to the use of an HTTP server and not a more secure protocol. Regarding the trustworthiness we can say that this requirement is also fulfilled since the Smart Condo only monitors the environment and has no direct control over physical objects. Finally, the requirement for ambience intelligence is also accomplished by collecting information that is used to infer patterns of sleep, irregular gait and falls.

DISCUSSION

In general the two systems meet almost all requirements; the common factor between the two systems is that they do not mention any protocol or algorithm to encrypt data that is transmitted via Internet. At this point we consider that the two systems could be improved. Although we have not considered this as a requirement for these systems we think that the use of wearable computing in the future can be an asset for such systems. The use of BAN's [ban] integrated in the clothes of patients may be an advantage in collecting information and monitoring of the patients clinical status in real time.

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