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Smart Homes for Healthcare

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Abstract. Smart Homes may improve the care received by the elderly and those with disabilities that prevent them from conveniently accessing care from providers. This paper examines the structures and mechanisms of Smart Homes, explores the advantages and disadvantages for patients receiving care from the comfort of their own homes and describes a model that can be used to view the needs of patients involving Smart Home technologies.

Keywords. Smart homes, home health monitoring, telehealth, mobile health

Introduction

The design, development and implementation of Smart Homes has emerged as an important international trend. In as much as smart phones have become a necessity for everyday living, the trend towards establishing smart homes as the dominant technology has also led to the rise of a global societal phenomenon. Aspects of Smart Homes may already exist in many homes in our community, such as Bluetooth powered light bulbs, security cameras, wireless doorbells, smart TVs, and Amazon Alexa, which is a cloud-based voice service that offers customers the capability to build natural voices for a more intuitive way to interact with their technology [5]. The ideal state between human and computer interaction is to achieve mutual understanding using the provided medium of communication. It is not sufficient to have technology available, but rather, to have technology that can easily interact with people to achieve a desired outcome. When Smart Homes are considered within the context of providing healthcare, researchers and health informatics professionals must consider the number of intricate and complex connections of such devices so their potential can be fully realized, in helping to monitor a citizen's health issues and to help patients manage their illnesses within the comfort of their own home. The objectives of this paper are to: 1. Define a smart home, 2. Describe a model that can be used to consider technologies used to equip Smart Homes for the purpose of providing health care services, and 3. Discuss the benefits and challenges of making homes "smart". According to Ambersheil and colleagues [1, p.1], "a Smart Home (SH) is typically equipped with a series of inter-related software and hardware components that work together to monitor the living space of the resident and understand their activities." As the population ages, there is a greater need for personal care and safer transitions from hospital to home care. Smart homes may reduce the number of patient trips to and from hospitals, especially if they are elderly patients, dementia patients or disabled patients that may not have caregivers available to accompany them. Smart Homes can potentially support these patients in living more independently. The

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following paper will examine the structure and mechanisms that operate within Smart Homes using a model based approach. The benefits and future of Smart Homes, as well as the challenges faced with the idea of Smart Homes will also be discussed. In the model we describe, we outline the four layers in the architecture of Smart Homes, and these will be described in greater detail below.

1. Structure and Mechanisms of Smart Homes

There are four Smart Home architecture layers, the physical layer, the communication layer, the data processing layer, and the interface layer [1]. The physical layer is responsible for sensors in the environment and physiologic sensors. The communication layer is responsible for wireless and wired sensor networks. The data processing layer is responsible for data storage and machine learning, and the interface layer is responsible presenting information and data to the residents and their care providers (see Section 1.1 below) [1].

1.1. The Model of Smart Homes

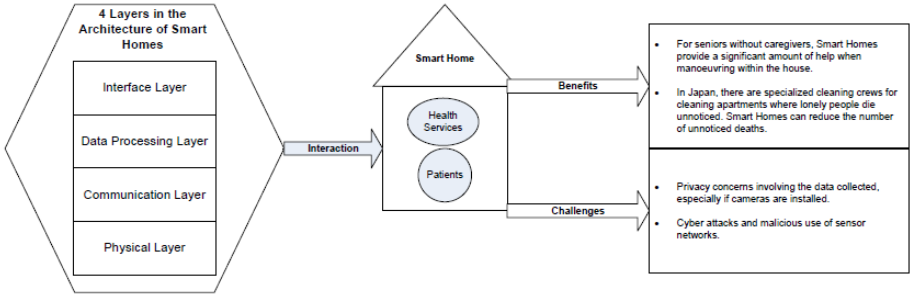

Figure 1. Smart Home interaction with patient

1.2. The Physical Layer

In the physical layer, Smart Home sensors collect the data and transmit it through the communication layer to the processing layer for activity analysis. The output of the analysis could be in the form of alerts or specific information that is delivered through the interface layer to the stakeholders [1]. Within the physical layer, there are two important categories of sensors, discrete state sensors and continuous state sensors. Discrete state sensors have a binary output for representing the state of objects or residents [1]. Examples can include door opening or closing, and lights turning on and off. Within this category of sensors, commonly used state sensors are Contact Switch Sensors (CSS) used for detecting the state of objects. Compared to discrete state sensors, continuous state sensors can be in simple or complex forms, such as numbers, images or sounds [1]. Commonly seen sensors in this category are environmental sensors that capture temperature, humidity, pressure, noise and light data; for example, AlarmNet

supports assisted living and monitoring, and operates using body area networks to obtain physiological data from patients [1].

1.3. The Communication Layer

The purpose of the communication layer is to connect all of the components together. Low-powered wireless networks allow power sensitive devices, such as sensors, to consume the minimum amount of energy possible in collecting data [1]. ZigBee is the most used standard, and is commonly used throughout U-Health or ubiquitous health [1]. U-Health is designed to take into account 12 different types of wireless sensors that record heartbeat, body temperature, blood pressure, motion, location, blood sugar, SpO2, dehydration, cholesterol, humidity, smoke and temperature [1]. Another type of communication is power line communication. These technologies allow Smart Homes to gain access to "universally available electrical communication terminals as the communication infrastructure" [1]. For example, KNX is one of the most successful heterogeneous protocols used in Smart Homes. Various types of media, such as radio frequency, power line and twisted pairs, and IP protocols are used by sensor designers [1]. Lastly, there are personal computer networking protocols and mobile telecommunication systems. The work in this area has included the use of Wi-Fi access points and the transmission of text, digitized voice, and other types of data.

1.4. The Data Processing Layer

Many Smart Homes apply fuzzy logic in the building and monitoring of systems. A fuzzy rule would take the form of the following: "*IF Resident_stay_in_bed for Long and bed-room_TV=OFF then Class_Risky"* [1]. Aside from fuzzy logic, there are also Artificial Neural Networks. These are made up of "highly interconnected processing elements, which process information by their dynamic state response to external inputs" [1]. With these capabilities, artificial neutral networks are able to classify activities, predict activities and control appliances.

1.5. The Interface Layer

According to Amiribesheli, [1], there are four different groups of users for a typical Smart Home; residents (dementia patients, disabled people, elderly people…etc.), informal caregivers (family members), social caregivers (care homes, professional caregivers), and formal caregivers (doctors, nurses…etc.). With these users in mind, an emerging theme is that elderly individuals may have limited short-term memory. Therefore, the design of user interfaces must support natural user interfaces, such as gesture recognition and speech recognition [1]. An example would be the Sweet-Home project, which proposed a voice interface for residents that helps to control the features of the home, such as window blinds, lights and kitchen appliances [1].

2. Benefits of Smart Homes

For seniors who are without caregivers, Smart Homes can provide a significant amount of help when maneuvering within the house or for monitoring one's own health status. TELUS has a Home Health Monitoring platform that interfaces with patients who have chronic diseases so patients can monitor their blood pressure and other health issues by transmitting vital sign and other health information to their healthcare providers [2]. TELUS suggests that "Patients with chronic conditions such as congestive heart failure (CHF), chronic obstructive pulmonary disease (COPD), diabetes, asthma, hypertension and some other health conditions can benefit from an home health monitoring (HHM) programs leveraging remote patient monitoring technology that typically last from three to six months" [2]. This HHM platform consists of a patient station and a clinical station. The patient station consists of a simple interface that includes vital signs entry, question and answer information, and educational material, while the clinical station consists of a clinical editor, monitoring plans and protocols, patient data and records as well as analysis and reporting screens [2]. If a Smart Home is an iceberg, then the TELUS HHM technology is only the tip of an iceberg, because the functions of Smart Homes represent an expansion of the capabilities supported in the HHM solution. With a Smart Home, the future of health care may change significantly.

2.1. The Future of Healthcare

The future of health care may include sensors and algorithms implemented as devices in a Smart Home [3]. Suggested sleep tracker mattresses can analyze sleep quality, microchips in a toilet could detect changes in urine, smart scales may measure changes in weight, and digital mirrors will detect facial skin cancers and changes in facial movement. If any of these markers exceed the normal level of the resident, a report will automatically be sent to the resident's physician or nurse. The physician will then contact the patient to book an appointment for a check-up or a nurse will contact the patient to assess their health status. The ideas proposed are not insurmountable, as with big data analytics such as IBM Watson, this information can easily be analyzed to assist in early diagnosis, treatment, or prevention of diseases. According to the Medical Futurist [3], "in Japan, an estimated 6.24 million people aged 65 or older were living alone in 2015…there are already clean-up crews specializing in cleaning apartments where lonely people died unnoticed" [3]. Smart Homes can lead to the recognition of health conditions and prevent senior deaths. Smart homes will allow for constant monitoring of individuals in their home for potential health issues. To illustrate this, Healthsense currently monitors 20,000 residents in assisted living communities, and has conducted a pilot project to expand this monitoring to private homes. A cohort of 34 older adults participated, and the results indicated a 50% decrease in emergency room visits compared to those who did not have the sensors [2].

3. Skepticism of Smart Homes

Researchers have identified a number of issues associated with Smart Home technologies. A major concern is privacy, especially if there are video cameras in the room. If sensors are placed in homes, there can be issues of "sensor compromise, eavesdropping, privacy

of data, denial of service attacks, and malicious use of sensor networks" [1]. Ethical studies will also need to be conducted in order to determine whether the use of sensors in the home is ethically correct, even if they are for legitimate health care purposes. Residents will also need to be informed thoroughly of how and what data will be collected about them. Smart Home implementers will need to ensure that patient data will be appropriately used and prevent hackers from stealing and selling the information to third parties. Lastly, the usability, workflow and safety of Smart Home technologies will need to be studied [4].

4. Conclusion

As technology advances and data collection methods mature, it is inevitable that the current healthcare system will undergo a paradigm shift to keep up with the changing needs of the population. There are both benefits and challenges in the use of Smart Homes, with the main benefit being an increased awareness of one's health status, and the main challenge being privacy issues. As mentioned earlier, the biggest groups that benefit from Smart Homes are seniors, disabled patients and dementia patients who are not able to be accompanied by caregivers on a daily basis. Smart Homes can assist them to live more independently and comfortably by reducing the amount of travel to see physician offices. However, the residents must be aware of where the sensors are located and which information will be collected about them so that the issue of privacy can be fully addressed as well as understand their interactions with these technologies. In addition, future studies should research into Application Programming Interfaces API) in order to standardize the integration of monitoring devices into the Smart Home. APIs act as an architect's blueprints for building Smart Homes, hence it determines the how the technology will be oriented to create the ideal user experience. The future of Smart Homes looks promising, but in order to have it safely implemented, more pilot studies will need to be done, and the technology will need to be continuously improved throughout each study.

References

[1] M. Amiribesheli,, A. Benmansour, A. Bouchachia. *A review of smart homes in healthcare*. 2015. Retrieved from https://doi-org.ezproxy.library.uvic.ca/10.1007/s12652-015-0270-2

[2] TELUS Health. *Patient and Consumer Health Platforms*. 2018. Retrieved from https://www.telushealth.co/health-solutions/patient-and-consumer-health-platforms/products/home-health-monitoring/

[3] The Medical Futurist. *Healthcare is Coming Home with Sensors and Algorithms*. 2018. Retrieved from http://medicalfuturist.com/healthcare-is-coming-home/

[4] E. M. Borycki, A. W. Kushniruk. Towards an integrative cognitive-socio-technical approach in health informatics: analyzing technology-induced error involving health information systems to improve patient safety. *The open medical informatics journal* **4** (2010), 181.

[5] Amazon Alexa. *Why Alexa?* 2018. Retrieved from https://developer.amazon.com/alexa