A Model of a Proactive Ambient Assisted Living System to Monitor Elderly People in The Kingdom of Saudi Arabian

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Abstract—The ageing population has been designated as a challenge to governments. The number of elderly people in the Kingdom of Saudi Arabia (KSA) will continue to increase rapidly, which will lead to a high expenditure in healthcare facilities. Elderly people are vulnerable to decline in their health. Therefore, Ambient Assisted Living (AAL) monitoring technology is advised to improve their quality of life and deliver the elderly with services and technologies that help them in their daily activities so that they may live independently in their homes for a longer time. The main goal of this paper is to develop and design a new concept for monitoring elderly people in their homes in KSA. We propose a Model of a Proactive Ambient Assisted Living System to Monitor Elderly People in The Kingdom of Saudi Arabian, and predicts and indicates potential events for early intervention. We envision that the AALMPS can fulfil the needs and requirements of elderly people and assist the Saudi government to make suitable provision for issues associated with the ageing population.

Keywords—Ambient Assisted Living, Elderly People, Proactive Monitoring System, Kingdom of Saudi Arabia

I. INTRODUCTION

The United Nations defines elderly people as people 60 years old and above [1]. The ageing population in the Kingdom of Saudi Arabia (KSA) by 2100, will increase rapidly by 33.5% [2]. Approximately 20.7% of elderly people appear at Primary Health Care (PHC) facilities and there is a lack of diagnostic facilities [3]. On some occasions, this leaves elderly people being unable to be allocated beds at hospitals [4].

A study conducted in 2013 in KSA for 10,735 participants over 60 years of age showed that 45.8% take medication [5]. A survey of 2,095 participants demonstrated the high percentage of risk of Obstructive Sleep Apnea (OSA) among the elderly (≥60 years) which was 41% [6]. Worldwide, falls are also a major concern amongst elderly people [7].

Heart failure (HF) and cardiovascular diseases are considered major concerns that affect elderly people in KSA [8], [9]. “Cardiac failure is an inability of the heart to deliver blood (and therefore oxygen) at a rate commensurate with the requirements of the metabolising tissues at rest or during light exercise” [10]. Many elderly people face declines in their health when they become older, and need some support in their daily activities, as well as facilities to monitor their health [7], [11], [12].

These demographic transitions create a set of challenges regarding their quality of life, including social communication and care, health, autonomy, shortage of professional carers, and utilisation of institutional services [13], [14]. These challenges require novel approaches for dependable self-adapting technological innovations. AAL is advocated as a potential form of technology that can be developed to monitor elderly Saudi Arabians based on results of a survey conducted in 2015 [15].

This paper is organised as follows: Section II includes population statistics. Section III discusses related work. Section IV provides the proposed AALMPS framework. Finally, the conclusion and future work are presented in Section V.

II. POPULATION STATISTICS

The world population in 2015 was 7.34 billion (bn). This number is projected to reach 8.5bn in 2030 and 9.7bn in 2050. By 2100, the population will be 11.2bn. In fact, people aged 60 years and over comprised 12% of the world population in 2015. Further, the number of elderly people in the world is expected to be 1.4bn by 2030 and 2.1bn by 2050, and might increase to 3.2bn in 2100 [2].

The population of the KSA in 2015 was 31.5 million (m) and is estimated to be 39.1m in 2030. This number will increase to 46.1m in 2050 and reach 47.6m in 2100. While the Saudi Arabian population continues to increase, the ageing population will also continue to increase rapidly [2].

The current status of elderly people in the KSA is controllable because the proportion is only 5%. However, the ageing population in the KSA will be unmanageable in the future, since the percentage will increase sharply to reach 20.9% in 2050, and this percentage will further rise to 33.5% by 2100 [2], [16], [17].

The increase in the ageing population worldwide compared to the rises in the world population presents challenges for both healthcare provides and elderly people [7]. In particular in the KSA, the growing number of people included in the ageing population presents many challenges to the Saudi Arabian delegations: 1) the increment of persons requesting pension benefits will increase; 2) the economy will decrease; 3) healthcare expenditures will increase and 4) spending will be more and saving will be less [16].

These challenges and issues demand professional, advanced approaches for trustworthy, self-adapting technological innovations. AAL is recommended as a potential form of...
technology, which can involve assisting and helping elderly people to overcome these challenges.

Therefore, this continuous growth in the number of elderly Saudi Arabians requires the development of a framework using AAL in order to improve the quality of life, independent living, the chances of living longer, health, and the ability to stay active.

III. RELATED WORKS

A. Ambient Assisted Living (AAL)

AAL is an innovation that improves the quality of life of elderly people and has a great potential for meeting the requirements of elderly people by using technologies [18], [19]. The origins of AAL can be attributed to home automation and assistive domesticity [20].

AAL technology plays a prominent role in providing elderly people with independent living, living longer, continuing daily activities, improving social communication, monitoring their health, decreasing the cost of care, and staying more active [12], [19]–[24].

B. AAL Monitoring Applications and Projects

Peetoom et al. [25], stated that [26] demonstrated the first monitoring technology, which monitors elderly people’s health status remotely. Further, [27] they clarified that the first fall monitoring system was designed in the early 1970s, which uses a button that is pressed to send an alert message.

Many studies have identified the needs and reasons for using AAL technology to monitor elderly people, including fall detection, sleep monitoring, presence detection, physiological parameter tracking (heart and breathing rates and gait), physical cleanliness, routine action monitoring (Activity of Daily Living), Parkinson’s disease, diabetes, Alzheimer’s disease, posture detection, location tracking, health status, overweighing, medical guidance, treatment prescription, and economic reasons [28]–[35]. Therefore, significant research has been undertaken to study, design, develop and innovate AAL solutions to monitor elderly people and overcome these reasons. Thus, most applied and proposed monitoring solutions have used the following techniques: 1) in-home passive infrared motion sensor; 2) body-worn sensor; 3) video monitoring or optical sensors; 4) ultrasound passive system; 5) pressure sensors; 6) radio frequency passive system; 7) electric sensing; 8) sound recognition or audio sensors; 9) biological and environmental sensors; 10) ambient and environmental sensors and 11) Radio Frequency Identification (RFID) sensors [25], [30], [34], [36].

A number of research developments accomplished in the AAL field have enhanced the technological services available to elderly people. Many technologies and projects have been designed and deployed as Smart environments that can assist elderly people in living.

For example, a Smart home and personalized health monitoring architecture were developed to remotely monitor elderly persons by caregivers. The caregiver accesses the information by using a web server. Sensors are installed in the home and can also be worn, such as a webcam. A person needs to perform some activities to be monitored; for instance, he or she must weigh him/herself and measure his/her blood pressure every morning. This data is then sent to the healthcare centre. A smart phone receives the data and sends them to the web server via the Internet. In case of an emergency, an external support can be delivered [37].

iCare is a mobile monitoring system for the elderly. It consists of four sections: 1) devices; 2) a smart phone; 3) a server and 4) an emergency centre. It alerts the emergency centre when there is an emergency and calls an ambulance. It allows doctors to review the elderly patient’s health history record and provide the elderly with some advice [29].

MobiSense is an innovative mobile health monitoring system for the ambulatory wearer. It is composed of four tiers: the wearer; body sensor devices; web server and caregiver. The person wears sensors and the data are read from the sensors and sent to the person wirelessly. The data are processed and determine the activities, which are sent to the web server via the Internet. The caregiver examines the data and takes action whenever needed [38].

BeWell is an application and system support that is composed of software implemented on Android smartphones and the Cloud infrastructure. It consists of sensing daemon, mobile BeWell portal and mobile ambient Wellbeing display. It monitors elderly persons’ behaviours daily. Thus, BeWell provides feedback, which assists users in understanding the effects of day-to-day physical activity, social interaction, and sleep patterns on wellbeing [39].

Centinela is a human activity recognition system based on acceleration and vital sign data. It monitors five activities, which are walking, running, sitting, ascending, and descending. The system consists of a portable and unobtrusive real-time data collection platform. It uses sensing devices and a mobile phone. The sensing device connects via Bluetooth with a phone and then data are sent to the application server through the Internet [40].

Jin et al. [41] proposed a monitoring system that depends on different sensors to detect risky situations for the elderly. It is composed of four layers, which are sensor, client, repository, and infrastructure. For this system, an elderly person carries a smart phone or wears a fall detector. The smart phone sends the location and personal data via Bluetooth to an agent. If a critical event occurs, it informs the caregiver.

A healthcare framework was presented to predict the risk of lifestyle disease by using long-term activity monitoring and to create the activity pattern for each day. It is composed of three elements: activity classification; activity pattern generation and lifestyle disease prediction. The clinician and caregiver can monitor the activity database remotely via a web-based healthcare application [42].

A system was developed to monitor elderly people who live alone and independently. It consists of four stages: requirement analysis, conceptual model, architectural design and evaluation. The system is divided into two parts, software and hardware, and contains some sensors that are connected to a mini PC. The software part sends alarms to the alarms central and takes actions such as a call back [43].

A platform was designed to monitor elderly daily activities by using sensors. It assists doctors in planning treatments for the elderly with chronic diseases and then notifies them to target a treatment plan [44].
An in-home activity monitoring system was established to monitor elderly people with diabetes. It uses sensors and body wearable sensors, which use a laptop via USB to upload data to the Cloud. Persons receive a daily text message and a weekly health newsletter [45].

A practical multi-sensor activity recognition system for home-based care was designed to monitor elderly people’s daily activities. The proposed system uses multi-sensor worn on wrist to discover the nine ADLs of an elderly person. The system is helpful for elderly people who live independently. It assists nursing to monitor them [46].

Suryadevara et al. [47] designed an AAL framework for Smart Home Monitoring System. It is composed of three modules: instrumentation; communication technology and data processing. It uses AAL Middleware to connect these components. It captures data from sensors and uploads it to a website. It sends an alert message to the caregiver if changes happen in the elderly person’s daily routine.

Alumona et al. [48] proposed a remote patient monitoring system that consists of three layers: wireless body area network (WBAN); personal server using Intelligent Personal Digital Assistant (IPDA) and a medical server for healthcare monitoring. Wearable sensors are attached to the patient’s body to closely monitor any changes in the patient’s vital signs. It provides a real-time response to retain the best health position. The data are collected from WBAN and are processed. Then, the crucial data are prioritised and forwarded to the medical server. Some treatment advice can be sent to the patient. If there is an emergency, the doctor takes action.

One study found a home sensor monitoring system for discovering early changes in health conditions for older people. Sensors are installed in a home, and then data are stored on a secure server. The data are analysed and observed daily. When changes in the user’s data patterns occur, an alert email will be sent to clinicians. This email allows clinicians to log in to a portal to visualise the patterns of the person [49].

A remote health monitoring system for elderly people was demonstrated to deliver an emergency alert to caregivers when there is a need for help. It focuses on monitoring heart rates, breathing activities and room temperature measurements. Sensors are installed in a home and then are connected to an Android mobile device via Bluetooth. An alert message is sent to caregivers when it is required [50].

However, the literature review indicates that there is no professional design or framework that can fulfil the needs or requirements of elderly people in the KSA. Therefore, the framework we propose will be advocated to provide the elderly people in the KSA with a better quality of life and support them to live independently in their desired environment.

IV. PROPOSED AALMPS FRAMEWORK

The proposed framework assumes that the home of the elderly person is equipped with a set of sensors based on the needs of elderly persons, such as temperature sensors, emotion sensors, a camera, etc. The most important concerns for the framework are cost efficiency and that they can be retrofitted.

The sensors should be installed easily and be flexible to be updated and not require remodelling of the home. Thus, the sensors will be positioned on walls, doors, floors, ceilings, and furniture. Further, the elderly person can wear some of these appliances, such as the Smart watch.

The contribution to knowledge involves addressing the ageing population phenomenon, which is rising in the KSA, by developing a Model of a Proactive Ambient Assisted Living System to Monitor Elderly People in The Kingdom of Saudi Arabian. The proposed model will support stakeholders, decision makers, elderly people and healthcare providers (Community of Practitioners (CoP)) in adopting the AAL technology as tools to provide elderly people with quality of life and the ability to live independently. The rationale beyond developing the model incorporates the following characteristics:

- **Uniqueness:** AAL technology is a new concept in the KSA, and to the best of our knowledge there are no studies that have investigated the use of AAL technology to address the ageing population’s challenges and issues. Thus, this proposed model is unique.
- **Efficiency:** Cost is a critical factor that affects the adoption of any technology. The model proposes a low-cost installation of tools such as smart watches, sensors, appliances, maintenance, etc. This is a competitive feature to adopt and implement the model. Hence, the proposed model is efficient and is designed to retrofit to existing homes.
- **Responsiveness and Proactivity:** The elderly person is vulnerable to health issues. In some cases, instead of reacting after something occurs, it is important to step back and be proactive and monitor the health of the elderly, likely preventing medical actions is extremely important. Therefore, the proposed model is both responsive and proactive.
- **Flexibility:** The sensors are installed easily and are flexible so that they may be updated and not require remodelling of the home. Thus, the proposed model is flexible using emerging technology and wireless systems.

In this section, we describe the model architecture, which includes seven layers and the operational phases of the proposed model are shown in Fig. 1, and are discussed as follows:

1) **Data Acquisition and Processing (DAP) Layer**

The first layer can be defined as the process of transferring signals, such as heart beat and motion sensors etc into a format that can be read [51]. DAP is responsible for collecting real-time data from different sensors, which capture the data from elderly persons in accordance with the assignments of each sensor, such as a Smart watch that measures heart rate. The data is transmitted via Bluetooth technology and then synchronised by using a mobile app or by using a computer with connectivity installed; the data are then transferred wirelessly to a portal.
2) Communication Structure (CS) Layer

The communication structure is the backbone for the proposed model. It consists of three types of networks: Bluetooth, wireless, and Internet. The structure of communication is designed to be more secure and reliable. It requires the availability of the Internet that will help upload the data from the Smart devices, such as a phone or a laptop, to the online portal via the wireless network and connect the Smart devices with the sensor via Bluetooth. An overview of the communication structure can be seen in Fig. 2.

3) Data Integration (DI) Layer

The data integration layer is the combination of data silos from different sources, which then delivers a coherent and consistent valuable view of the data [52]. Therefore, the data for this proposed will be collected from different sensors installed in the home of the elderly person, including motion sensors, temperature sensors, Smart watch, etc.

This layer is the core of the proposed model because it integrates different structures and formats of data that are retrieved from different sensors into the data hub. The data collection should be more efficient and consistent since it is filtered, cleaned, and uploaded to the hub as shown in Fig. 3.

The process of data integration consists of two types of technologies: video database and imagery database. The hub is responsible for storing and saving all applications and software. The hub can be a warehouse that integrates different data and converts it to information. The information can then be processed through the knowledge-reasoning layer using a rule-based expert system.

4) Cloud Computing (CC) Layer

Cloud computing can be defined as a technique that provides computing resources through the Internet [53]. It allows the model to store and share the applications, software, processing resources and data to Smart devices.

One of the most important features of the Cloud is the cost of hosting. It is low cost compared with in-home hosting, which includes a high cost to build the infrastructure [53].

The Cloud assists our model with efficiency and the ability to react and respond to the system quickly, whenever and wherever. This layer is the primary layer that connects the data integration layer with the reasoning layer.

5) Knowledge Reasoning (KR) Layer

The proposed model is designed using a knowledge base system and reasoning to build a decision support system (DSS) for AALPMS by using a rule-based expert system to
help in making proactive decisions. It processes and analyses large amounts of data and translates them to information and knowledge. The knowledge will be viewed by users and used to provide proactive solutions that support medical actions.

6) Visualisation (V) Layer

In reality, a person favours graphics, maps, visuals and charts that present realistic views of the information. The system takes real-time information and delivers knowledge that is shown as patterns. The knowledge is generated by the knowledge reasoning, which translates the integrated data to meaningful visualisations. It provides insights to the users.

The system’s visualisation can be seen and monitored by a mobile, laptop, or any smart devices. It is considered a value-added service, especially for the elderly’s family, relatives and healthcare providers. This layer is used for visualising the data that are received from sensors and stored in the Cloud. Eventually, visualisation assists us in making designs, which express a story about the data.

7) Proactive Control Centre (PCC) Layer

Elderly people are subject to physical and mental issues. Their health is completely different from when they were younger and health is a very complex process. Therefore, health problems might happen suddenly and accidentally.

Sometimes, taking action after things happen is not effective. Thus, instead of reacting when something occurs, stepping back to be proactive and monitoring the health of the elderly, and likely preventing medical actions, is extremely important.

A Proactive Control Centre (PCC) predicts and knows what type of issues and problems could happen to the elderly person, thereby supporting appropriate actions that are tailored to the specific problems.

V. CONCLUSION AND FUTURE WORK

The number of elderly people has increased worldwide. The Kingdom of Saudi Arabia is one of the developing countries that will have dramatic demographic changes in the future. The ageing population in the KSA will increase by six times by 2050; this will put tremendous pressure on the government and society to find a sophisticated solution to cope with these significant trends. Therefore, AAL monitoring technology will be important to cope with issues related to the continued increase of the ageing population in the KSA.

Elderly people are often not willing to be treated in a traditional manner, as they have in the last decades. They intend and want to have a technological solution that provides them with a good quality of life, and supports them to live longer in their own home.

The proposed model is composed of seven layers: data acquisition; communication structure; data integration; the Cloud; knowledge reasoning; visualisation and proactive monitoring system. In the model, we developed the elderly people can be monitored remotely by both their family, relatives/caregiver and automatically by the AALPMS. The data collected from a variety of sensors, will be processed and integrated and will be delivered via a knowledge based system to provide indicators, which guide the AALPMS to implement the appropriate actions in normal or emergency conditions.

Our system is based on cost efficiency and is designed to be retrofitted to existing homes. Information will be gathered and discussed via a Community of Practitioner (CoP) and can be further used for building design standards for elderly people’s homes. The proposed model would help to save significant amounts of money that could be spent by governments to help cope with the issues related to ageing. Our system delivers a 24/7 monitoring system and proactive services, actions and feedback.

The ability of AALPMS to react before issues happen provides elderly people with a better quality of life, the possibility of living longer, and living independently and safely in their homes. The knowledge reasoning will be the key layer that guides the model either to visualise the data to be seen by family, relatives, or caregiver, or to detect early emergency conditions and provide a variety of healthcare services using AALPMS.

In the future, the sensors such as smart technology could be incorporated into a chip and implanted into a human body, but this would require extensive ethical discussion and approval.

Our future work will study the technologies that are used in the model to choose the appropriate technology. More details will also be provided about AALPMS. We will experiment using the model with key stakeholders and design a home architecture that uses a plug-and-play technique. The aim is to make it easier for elderly persons to use the sensor infrastructure based on their needs and requirements. The researchers will conduct a case study in the Ministry of Social Affairs in the KSA to test and validate the model. It is important to mention that this research is on-going.

REFERENCES

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