Experiences and Challenges of Providing IoT-Based Care for Elderly in Real-Life Smart Home Environments

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1 Introduction

Elderly population across the world is on the rise and municipalities along with caregivers are struggling to provide care due to limited resources. Sweden's elderly population is set to grow significantly by 2050 where the number of people between 65–79 years and 80 years and over is expected to increase by 45% and 87% respectively [1]. The same trend continues within Europe where 25% of the population will be over 65 years of age by the year 2020, and the age group of 65–80 years is predicted to rise by 40% from the year 2010 to 2030 [2]. The rise in elderly population has increased the stress on municipalities and caregivers; and has created the need for new healthcare solutions that are feasible, affordable and easily accessible to all. Smart homes equipped with sensors have already made life easier for those living in them for many decades now by providing home automation solutions. We are also witnessing an increase in the use of Information Communication Technologies (ICT) to assist elderly population and decrease in operational costs. ICT systems in assisting elderly population have an immense potential for providing in-home care to the elderly [3]. The advent of the Internet of Things (IoT) with low-cost and prolific sensors has furthered this trend of home automation and monitoring solutions being used for elderly healthcare [4, 5]. Alongside, the field of ambient assisted homes has continuously paved the way for providing an improved quality of life for those in need such as patients with dementia or chronic conditions as well as elderly living alone at home [5–7].

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R. Ranjan et al. (eds.), *Handbook of Integration of Cloud Computing, Cyber Physical Systems and Internet of Things*, Scalable Computing and Communications,
https://doi.org/10.1007/978-3-030-43795-4_11

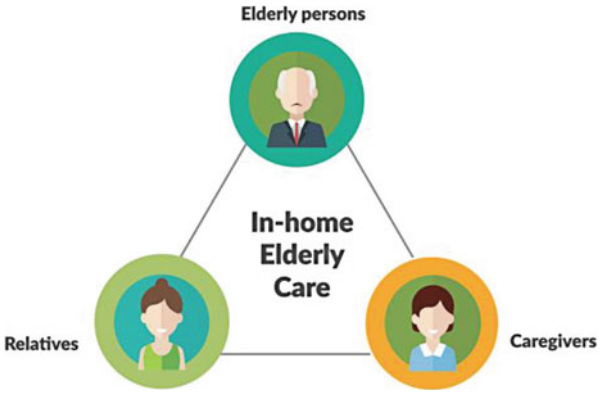

Fig. 1 Three key participants within in-home elderly care

We believe in the future, the advancements in healthcare will further enable the elderly to live longer and independently in their homes and sensors allow for the "*elderly to age in place for twice as long*" [8] as shown in the specially equipped senior housing facility where sensors monitor walking for risk of falling and respiration rate, pulse, etc. Research within the area of providing 'in-home elderly care' points towards the important role played by the elderly person's family [9]. Thus, based on existing research [9, 10] we highlight that 'in-home elderly care' have three key participants: the elderly, their relatives and caregivers as shown in Fig. 1.

Research in ambient assisted living has now existed for a few decades where technology is envisioned to help people live their everyday lives within their homes by adapting to their behaviors [6]. Further, the use of smart home technology for healthcare has witnessed an increased interest from the research community where data is collected within living labs to understand and analyze human behavior or primarily activities of daily living (ADL). There is extensive research in the last decade on using artificial intelligence (AI), machine learning and other techniques to learn, analyze and understand human behaviour within these lab environments [10]. A large pool of publically available datasets exists from different research groups and universities[1] ; researchers have applied different techniques on these datasets to learn, infer and predict different types of human behaviors or complex activities [10]. The understanding and inference of complex activities using knowledge and machine learning based methods can be essential for supporting the elderly and assessing long-term behavioral changes [11–13]. Such technology is envisioned to enable the elderly to live longer in their homes by providing timely support and assistance [10]. However, there still remain many challenges that need to be

[1]Datasets for Activity Recognition, https://sites.google.com/site/tim0306/datasets [Online] Access Date: 20 February 2018

addressed before such solutions are deployed in real-life and are commercially available for all to use [13–16]. Therefore, the real challenge is to take these smart home technologies from the lab environments to real-life homes and apartments with real users or inhabitants and then develop novel systems, which can provide timely assistance and support. Thus, making it important to understand the needs of each of the three key participants within in-home elderly care depicted in Fig. 1, and aim to facilitate them while developing healthcare solutions of the future.

In this chapter, we present our experiences and challenges faced with using off-the-shelf IoT-based smart home sensors [17] used primarily for home automation to improve the quality of life and provide support for the elderly living alone in their homes, their relatives and caregivers. The focus of our study is to deploy smart home sensors in real-homes, outside of the lab environment, gauge the interest of the elderly and their relatives, and understand how the relatives and caregivers can be supported. A rule-based notification system is used as an initial step to send notifications to the relatives based on the elderly's daily activities; this enables the relatives to participate more closely and assist the elderly who prefer to live independently. Thus, leading to the overall long-term goal of enabling the elderly to live longer in their homes with independence and dignity. This research is part of a pilot study, which is a first phase of a larger project aimed to provide elderly care in Sweden. The trial installations and the experiences will be used towards the next phase of the project. Our project aims to include a large number of elderly participants living alone in their homes in Sweden and leading to the next step of applying machine learning and artificial intelligence (AI) to detect abnormal behaviors which can enable caregivers to provide timely care and support to the elderly.

This chapter is organized as follows: Sect. 2 motivates the need for using smart home sensors for elderly healthcare. Section 3 describes the current scenario in northern Sweden along with project goals and aims. Section 4 presents the system design and implementation as well as the deployment challenges faced and lessons learned. Sections 5 and 6 describe the interviews performed to learn about the participant's daily routines from such a system and discusses the feedback from using the system respectively. Finally, Sect. 7 presents discussion and conclusion.

2 Motivation

The increased longevity of human life has led to an increase in elderly populations across the world, which in turn will place a tremendous burden on healthcare costs in the years to come. The increase in elderly population in comparison to younger people implies that the ratio of working people to the remaining population is expected to become 2:1 from the current 4:1 [2]; this places an immense stress on caregivers in elderly homes and in-home healthcare services provided by the municipality who are already short on staff due to budget reasons. Further, there is an increased cost associated with these services on governments, municipalities and

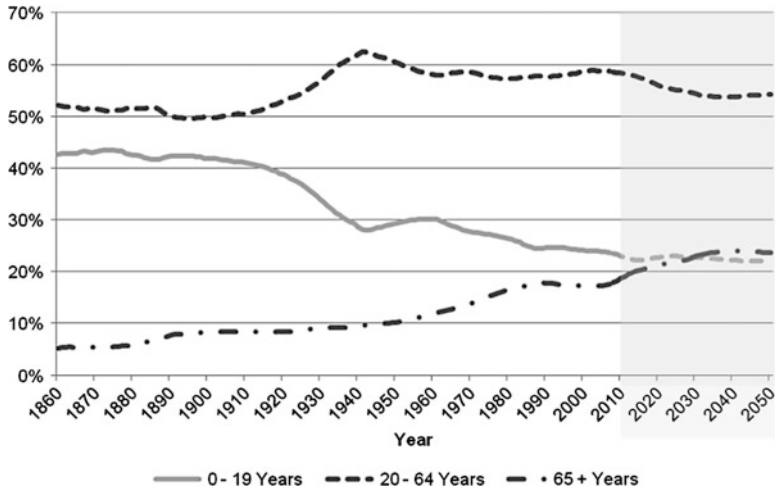

Fig. 2 The share of population for three different age groups in Sweden (Sourced from Statistics Sweden)

care providers. Therefore, there is a need for low cost, easy to deploy, adaptable and wide-scale solutions that can provide timely care to the elderly and assist the caregivers in meeting their needs. Figure 2 from Statistics Sweden[2] shows the increase in population for 65+ years group and is projected to increase more than 20% of the entire population.

In the city of Skellefteå in northern Sweden and neighboring regional areas, the trend is the same with a growing elderly population. Elderly people living alone either in their own homes or in nursing homes are provided care services by the municipality. The caregiving staff travels vast distances each day many times ranging from 1 to 5 depending on an individual's needs to help and assist them with different kinds of activities. There are mainly two categories of elderly people. One that are independent and perform all their daily activities on their own while the other group of elderly persons living alone may need support for activities such as cooking, eating food, cleaning, and washing; they may also sometime require just a regular checkup to know if they are healthy and are following their daily routine. In both cases, relatives often provide support to elderly people.

For the relatives, it is mainly about peace of mind to know that the elderly are doing well every day. At the same time, the elderly persons wish to feel secure and safe in the confines of their homes/apartments regarding any emergencies. It is essential for them that they receive timely support and emergency care for example, in the case of fall-related accidents or have a health-related incidence or when a person with mild dementia leaves the apartment at night. It is important however to

[2] https://www.scb.se/en/

note that while the relatives wish to know about the elderly person's wellbeing at the same time, the elderly should be comfortable in sharing this information. For the caregivers, it is essential to know details about activities and emergencies for which they provide day-to-day support. Therefore, these three essential participants within in-home elderly care can benefit from an IoT based technological solution to reduce their workload and mental stress, support their daily activity needs more efficiently and assist in providing timely care.

3 Scenario and Aims

In the first phase of the project, the aim is to explore the use of smart home sensors within the homes of the elderly and also, to build a ICT system that assists in providing care for them. The system aims to support the elderly as well as their caregivers and relatives. Further, this is conducted to facilitate the process of sending notifications to the relatives and caregivers for different types of activities and situations regarding everyday life of an elderly person. Thus, the overall goal of the project is to help the elderly live longer in their homes with independence and dignity. At the same time reducing the stress on the healthcare services and to provide timely information to relatives about the wellbeing of their elderly relative(s). To achieve the goals of the project, there arises a need for a system to be built that can handle heterogeneous sensors from smart home and healthcare domains such as, door/window sensors, light sensors, heart rate monitoring sensors, water and power meters. Further, it is important to understand how the previously mentioned sensors can be used to detect different kinds of activities, and build mechanisms within the system to generate the correct alerts and messages for the relatives and caregivers. The project also aims to understand the differences and similarities in the needs between elderly persons by using our system. To achieve these aims, there is a requirement to gain better understanding of the needs of each of the participants involved. This is achieved by interviewing the participants and in the first phase of the project, the elderly and their relatives were interviewed together to gain insight of living conditions and daily routines.

4 iVOS System Design and Implementation

In the iVOS[3] project, a number of off-the-shelf IoT devices such as smart pillbox, door and motion sensors, smart plugs, smart meters, etc. are used where different groups of IoT devices may belong to different service providers. Figure

[3]Stands for "IoT inom vård och omsorg i Skellefteå kommun" translated to English as "IoT in medical care and social service" in Skellefteå municipality

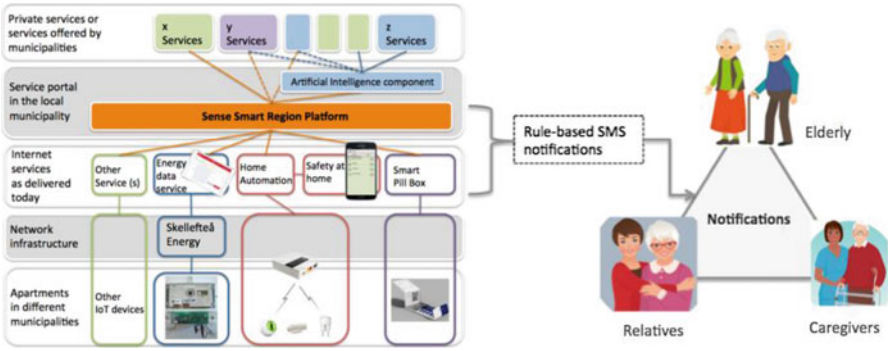

Fig. 3 iVOS system architecture and rule-based notifications

3 shows the iVOS architecture. The many different IoT devices are installed in the apartments of the elderly. Here, we present the first phase of the project where we considered the deployment in Skellefteå municipality. In this phase, the different service providers and IoT devices were explored and integrated alongside performing interviews with the first elderly users who volunteered to participate in the project. In Fig. 3, the bottom two layers show the different possible installations such as smart home sensors from Fibaro, smart energy meter and smart pillbox. The next layer above depicts the different service providers that can be part of the iVOS infrastructure and functions individually or be part of the larger Sense Smart Region (SSR) platform described in Sect. 4.2. These are services that are provided by different service providers as of today. However, we envision that in the future these service providers will come together in a smart city platform to provision enhanced services by sharing/providing data and using big data analytics by applying AI/machine learning. These new services are foreseen to be provisioned by another set of service providers based on the intelligence component underneath. The SSR platform is used as an infrastructure which brings together different service providers with infrastructures (such as sensors and smart meters) or individual services, enable access of data from these different service providers, perform advanced data analytics using AI/machine learning and then offer new intelligent services within the top layer. One key aspect is to be able to personalize sensing in homes so that requirements from households with varying needs can be considered. This is crucial for applications, which will use AI/machine learning techniques for example to detect anomalies in an elderly person's daily behaviour inferred from a variety of different types of sensors. Thus it is required for us to be able to combine arbitrary system installations for sensing in homes by avoiding being locked into verticals provided by different proprietary service providers. The system architecture depicted in Fig. 3 aims at providing this ability.

4.1 System Description and Deployment

The apartments/homes are fitted with IoT devices/sensors from different service providers participating in the project. Fibaro sensors for home automation are used in the apartment/homes. The sensors collect different types of information regarding the elderly persons such as movement, light and temperature levels in the room, opening and closing of doors, smart plugs that record information about appliance use or if a lamp is switched on or off. The sensors are connected via gateways to their respective service providers which further push the data to the Sense Smart Region (SSR) platform[4] or in some cases the gateways can also directly push the data to the SSR platform. The information sent is secured via encryption/HTTPS at the gateways located in the apartment/home. Thus, each home/apartment can have one or more gateways, which connect the sensors to the SSR platform.

4.2 Integration with SSR Platform

The SSR platform enables the creation of smart products and services for both urban and rural areas. The overall aim is to combine different types of data from real and virtual sensors along with open data to create valuable and interactive experiences for the smart products and services. Figure 4 below shows the architecture of the SSR platform. In the iVOS project the data from IoT devices installed in apartments is communicated to enterprises back-end systems, and then forwarded to the SSR platform to be combined and for classification by machine learning classifiers. The communication between enterprises and the SSR platform is done via the standardized NGSI 9/10 data model. This collected data can further be processed to send alerts to relatives and caregivers regarding the activities of the elderly. The SSR platform is an enabler for different and wide variety of application providers who like to use data originating from the IoT devices within the smart region. The SSR platform utilizes different components from the FIWARE[5] IoT middleware to enable the different processes of data handling, processing and storage. It is also possible to use different types of communication technologies.

4.3 Participants and Sensor Installation

In the city of Skellefteå, four persons participated in the project, three females, Carin (90 years old), Elise (82 years old), Ingrid (80 years old) and one male,

[4] https://sensesmartregion.se/

[5] https://www.fiware.org

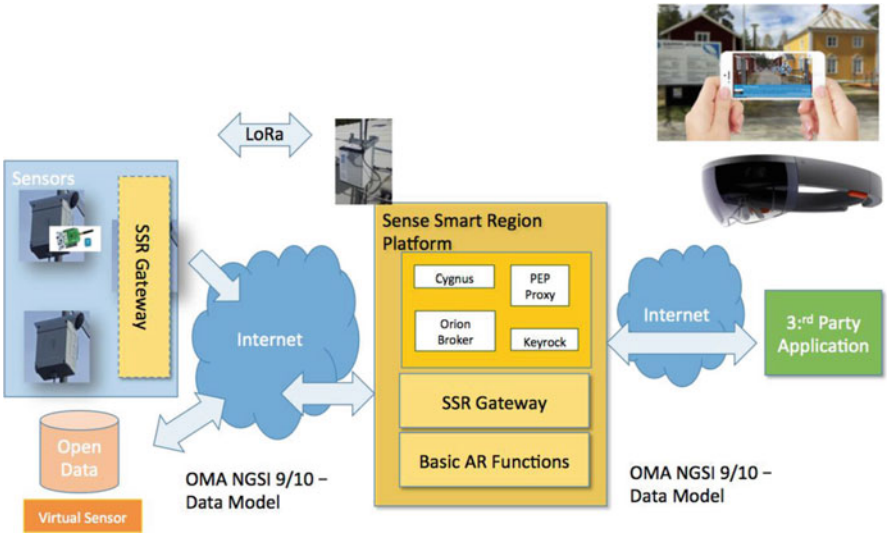

Fig. 4 Architecture of Sense Smart Region (SSR) platform

Roger (90 years old) (Ficticious names used). All four live alone in apartments, which are part of elderly homes provided by the municipality. Carin and Elise live independently and use no support from caregiving home services currently while Ingrid and Roger have caregivers visiting them four times a day since they have Alzheimer. Roger has early stage Alzheimer but Ingrid's condition is advanced. All four apartments they live in are similar in layout though not exactly the same in terms of how the furniture and living space is organized. At the start of the project, sensors were installed in all four apartments. The generic plan of the elderly home with the sensors installations is shown in Fig. 5.

However the two participants with Alzheimer, Ingrid and Roger could not continue due to their condition till the end of first phase of the project. Ingrid had to leave due to her deteriorating condition at an early stage while the remaining three participants continued till the end. Roger had to leave a little before the end of phase one. Carin and Elise who are healthy and independent without any caregiver support gave consent to continue their participation for the next phase of the project as well. This further confirms that healthy and active elderly individuals are more accepting and open towards new technologies as compared to those who have ailments like dementia as also suggested in [6].

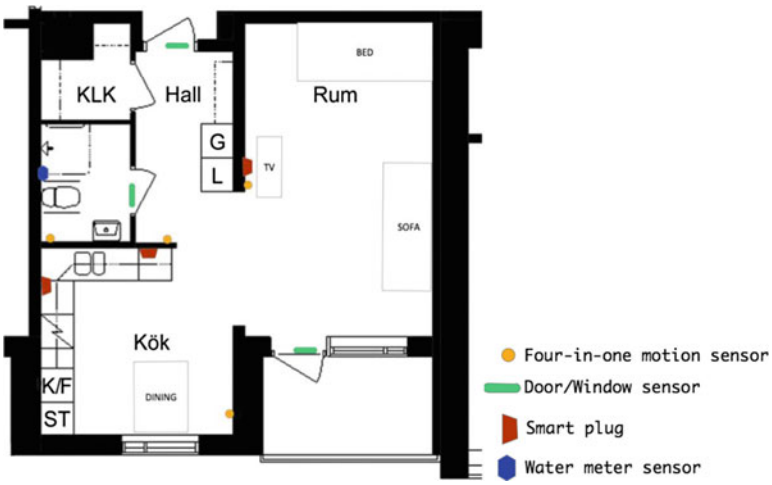

Fig. 5 Generic layout of an elderly person's apartment with sensor placements

4.4 Deployment Challenges: Installation Experience, Challenges Faced and Lessons Learnt

The installation of smart-home sensors is kept simple in view of the number of homes this could be installed in the long run. In the case where smart home sensors are merely used for home automation this process is linked to the direct need of the kind of automation required by the inhabitants. However, when the same sensors are used for providing healthcare support to the elderly in their homes as well as their relatives and caregivers, there are a number of issues that are important during installation. In this section, we present our experience with the deployment process and some of the challenges faced as well as the lessons learnt for future deployments.

4.4.1 Layout of the Apartment and Placement of Sensors

The layout of the apartment and the living conditions determines the placement of all smart home sensors such as motion sensors, door/window sensors and smart wall plugs. In addition, the organization of the living space in terms of furniture and furnishings also affects the placements. Lastly, the use of different spaces and door/windows can also have an impact.

4.4.2 Motion Sensors

The number of motion sensors installed depends on the different kinds of activity that the elderly perform and which of these activities is of interest. It is also important to know which locations are these activities performed in. In terms of technical aspects it is important for the case of Fibaro motion sensor to consider its orientation and the area it covers. It is important to note if there are any overlapping locations/areas where more than one motion sensor will be triggered or none of the installed sensors will be able to cover it. There is a need to find ways to eliminate this overlap or minimize it and maximize the locations covered by the motion sensors. This is important especially in the data analysis phase where such locations can be misread as a person being in two locations at the same time. Further, it is important to understand for each location where this sensor should be placed, for example which wall and direction of sensor as well as how is the furniture positioned to minimize obstructions.

4.4.3 Door/Window Sensors

For door sensors, it is important to place them so as to minimize false readings when the door opens or closes. The door sensors should be placed at a location where there is minimum possibility for the inhabitants to be able to touch or knockout the sensor inadvertently while going in and out of the door. Other issues that can arise are if the door does not close properly or the latch is loosened as this may cause the door to move when there are windy conditions that can cause false readings.

4.4.4 Wall-Plugs

During the placement of wall plugs to monitor the appliances and lamps there is a need to know which of these objects are most important in the daily lives of the inhabitants. It is required to see if all electric appliances or objects are used or the use of a few most important ones are sufficient as this affects the overall cost of sensor procurement.

4.4.5 Other Sensors

The other sensors that were considered for deployment in phase 1 were water meters for bathroom and kitchen activities as well as wearable wristband for body movement activities such sitting, standing and walking. However, this was discontinued after initial use due to issues with the particular wristband used in terms of its data. In future other wristbands may be considered. Another reason for not using wearables at this phase was that the elderly already had an emergency wristband where the municipality provides support when the elderly pressed the

emergency button. The wearing of two wristbands often led to confusion in distinguishing between the two bands for some elderly participants. To avoid this risk it was decided not to use the wristbands.

4.4.6 Fixed Installations and Limiting Accessibility of Elderly to Sensors

During installation the sensors need to be fixed on the walls and doors in a way so they do not fall off. The sensors if not installed properly can fall or come off from where they were placed. Once fallen, the inhabitants may move them around or they may lie on the floor for example under a chair or table and the data accuracy will be compromised. Similarly, with the wall plugs, they are placed outside the wall sockets and can be taken out by the participants or moved around. This may lead to a situation where the wall plugs are not being used or used for a different appliance or lamp then initially planned. In the latter case, the wall plugs will generate false data for example; the bedside lamp wall plug may be moved to the lamp in the lounge or the radio at the bedside. It is however possible to use the new Fibaro wall plug sensors, which are embedded behind the sockets in the wall. This will add additional installation cost due to the need for an electrician to install these wall plugs but will improve data accuracy. Accessibility of sensors to the elderly participants must be limited since they are interested to explore the devices due to interest in how they function.

4.4.7 Concerns of Privacy

There are also issues about privacy. For example, at a workshop in beginning of the project and during installation the elderly were given details of the sensors and how they function. However, Ingrid and Roger misunderstood the motion sensor to be a camera after installation due to the light it emits when motion is detected. It is important to understand that some of the elderly belong to a generation which may have little to no understanding of such new sensor technology and they are at a stage of their lives being 80 and 90 years old as well as coping with Alzheimer. This makes it difficult to explain the functioning of the sensors to them. Thus, it is required to place the sensors in a non-intrusive and inaccessible way. However, on the other hand Carin and Elise who are 90 and 82 years of age are very open and accepting of new technologies since they are active and keen on learning about new technologies. At the same time, Carin and Elise being open to new technology are cautious about their privacy since they are not willing to have a camera-based system in their apartments.

4.4.8 Elderly Comfort with Sensor Installations

Both the motion sensor and wall plugs emit some form of light while functioning. The elderly participants would like if this light were not present during night times as it can be distracting and interfere with their normal living. Thus, the use of smart home sensors for healthcare requires that the sensors are adapted accordingly and thought of in new ways to accommodate such requests. The installation of such systems should not make the elderly uncomfortable in their own apartment/home. This was taken into consideration and noted for phase 2 of the project to disable the light emitting from the sensors. The manufacturers of the sensors can consider such aspects and develop newer forms of sensors with minor adjustments that can allow for more comfort while deploying them for elderly care.

4.4.9 Continuous Checks and Monitoring

After the sensors are installed, there is a continuous need to make sure that these sensors are always working and always connected to the gateway and the SSR platform. A number of issues arise here which need to be addressed post installation. For example, checking for battery consumption, making sure that there are no changes in the positioning of the furniture of the homes/apartments, the door sensors are not generating false readings due to a door moving due to wind at night when it was left open for fresh air, to check if the wall plug sensor is not sending any data because the appliance is not used or if it is removed from the socket completely, the motion sensor in the bathroom has fallen and placed on the wash basin and this may affect its functioning and detection of motion. Thus, fixing such issues may involve occasional visits to the apartment/home to check on the sensor installations.

5 Understanding Elderly Participant's Daily Routines Via Interviews

In order to better understand the elderly participants daily routines and needs from such a system, interviews were conducted with the elderly and their relatives. Each elderly is a different person even though they may have similarities in their behaviour. To detect their activities using smart home sensors each elderly is interviewed to establish the ground truth for the activities that are detected by the rule-based model to send notifications to their relatives. The interview questions focused on some of the common things of interest from such a system for all participants such as daily routines which involved wake up/sleep times, breakfast/lunch/dinner timings, if they went out of the home/apartment regularly at particular times of the day or night, other activities that they performed during the day, the appliances they used most in a day, week or month, etc. Participants

were asked about the activities they performed immediately before sleeping and immediately after waking up. These questions were formulated to gain a deeper understanding into the daily behavioral patterns of the elderly.

After the installation of sensors, it was discovered that Ingrid due to suffering from Alzheimer could not take part any longer since she constantly tampered with the sensors and it was impossible to keep them out of her reach in this trial phase. Thus, the interviews were conducted with the remaining three elderly participants and their relatives. It was discovered from the interviews that the three different individuals have different patterns although there were some common baselines. For example, Carin and Elise had differences in sleeping patterns while Carin slept for 7 h without waking up even once at night Elise woke up twice every night to go to the toilet. Carin ate meals at precise times of the day while Elise had a range of time between which she ate her meals. Roger who has Alzheimer had visits from 'hemtjänst' or home services to support him four times in a day. One of these visits is during the night to check on him while he is sleeping. These visits have to be accounted for by knowing at what times of the day the caregiver visits so that the sensors were used only for the elderly participant's activity and not of the home care giver. It was observed from the interviews and from the relative's feedback that his behavior can vary due to episodes of memory loss. The relative was able to give insight into the behaviour that can be considered as normal when there is no memory loss for example, accessing the fridge to drink milk or a particular juice on their own without help of the caregivers, switching on the TV by themselves when alone in the apartment. The times of the day when he did not feel well he may end up sleeping or sitting on the sofa for long periods of times or on some days may not feel like getting out of bed. The common baselines between participants are that all routine activities are performed except the timings are different for different participants.

Other questions in the interview attempted to understand the expectations of the participants and their relatives from such a system. The participants were also asked if they would like to keep a diary to record their activities. However, this is perceived as an additional workload for them and they were reluctant to make such notes in a diary. This is understandable given there ages of 91 and 82 years for Carin and Elise and Ingrid and Roger who alongside being 80 and 90 years old respectively also have memory problems due to their condition with Alzheimer.

Further, it was gauged if the participants were willing to try and explore more sensors from the current installations to recognize specific behaviour that may not be possible to infer from the current deployment. The elderly were open to more forms of sensors as long as they were not intrusive and did not affect their current living conditions. The two female participants are interested to know more about their long-term behavior and to see how we can provide more advanced insight into their daily behavior. One additional safety measure that was asked for was to be monitored outdoors with positioning in case of falling.

5.1 Notifications

Different kinds of notifications can be generated regarding the elderly' daily lives and behavior. For the trials we developed on the different kinds of notifications to be received on a test phone for all participants. We set-up and received approximately 5–8 different types of notifications for 5 months to test out and observe the elderly's daily movement or object based activities. This was followed by sending notifications to the relatives phones for 6 months. However, the number of different types of notifications was reduced from the initial 5–8 notifications. This was done to reduce the load on the relatives and send notifications for what they considered as most important. Notifications linked to emergency situations, which need immediate and urgent attention, can be classified as alarms. However, notifications regarding their daily routines can be either classified as positive or happy notifications and on the other hand these can also be just alerts regarding activities which need attention or support from the relatives and/or caregivers.

5.2 Positive Notifications

The need to send notifications to the relatives and alerts about the various activities of the elderly was the primary focus here. Rule based activity notifications were generated and sent to the relatives in this phase via SMS service. The focus is not about merely generating an alarm or alert about an emergency situation but also about enabling the relatives to be better in touch with the elderly participants in relation to their daily well being and behaviour.

It was discovered during and after the interviews with the elderly participants and their relatives that the relatives were interested in finding out if the elderly were doing well during the day. Merely knowing about activities like waking up in the morning was of immense interest. In the case of Carin who is 90 years old, her daughter is also 70 years old. The daughter lived further outside of the town and she is happy to receive a notification every morning about when her mother wakes up. This is a non-intrusive way of knowing about a loved one without having to ring her. Ofcourse, they can talk over the phone later in the day but receiving an SMS notification about her mother waking up in the morning made her feel better.

5.3 Alerts

Other examples of such notifications that the relatives are interested in are, notification about the elderly going out of the apartment for an activity and returning back; a notification about the elderly in the bathroom for too long then normal. In case of Roger who has Alzheimer, the relative is interested in a notification if he

leaves the apartment at night between his usual sleep times. Such notification or alert can help make sure that they do not get lost at night.

It is necessary to send notifications about important activities and activities of interest but at the same time it is also important not to overload the relatives with large number of notifications regarding the elderly's activities. This can become over bearing for the relative and lead them to losing interest or become hard to manage. It can interfere with their daily lives as well. For the elderly this can be overly intrusive and they may not be comfortable with large amount of information to be shared with their relatives. Thus, in the trial we limited the notifications to what is considered most important by the elderly and their relatives as described previously regarding waking up notifications and leaving the apartment/home.

6 Feedback from Elderly and Relatives

After running the trial for 6 months and sending of preliminary rule-based notifications, feedback was collected with a second set of interviews. It is important to note that this is the first time that the elderly and their relatives were involved in such a trial. The overall response to the trials was positive. The two females, Carin and Elise that were able to participate in the complete trial agreed to continue participation into the next phase of the project due to their very positive experience and were supportive of the trial. The relatives found the notifications very useful and reassuring. They were happy to receive them everyday and mentioned to continue receiving such notifications in the future. During the trial there were interruptions due to certain technical issues and the relatives expressed that they missed the notifications and were eager for them to resume at the earliest. For example, one of the son's had become used to checking every morning on the 'Waking Up' notification for his mother. However, they were also excited to know more about the second phase of the project where they would like to receive notifications about other kinds of activities, these could be long-term observations about elderly's behavior or anomalies in behavior, emergency health situations such as falling down. In the first phase, the notifications were sent only to the relatives and in the next phase caregivers will also be included. These emergency notifications can enable the caregivers to provide timely emergency care and support.

7 Discussion and Conclusion

There were a number of deployment issues when installing and maintaining smart home sensors for provisioning healthcare to the elderly in their apartment/home. These involved placement of sensors based on layout plan of the apartment and the organization of living space, location of different activities and prioritizing the most important ones for notifications. Some issues that need to be considered arise from

privacy and ethical aspects. For example, the access of such data and notifications should be limited to only those responsible for care and the family members that the elderly gives responsibility regarding their wellbeing. It is important to have a hierarchy of persons who receive notifications in case a family member is on vacation. Further, it is also important to have a mechanism to notify the system when the elderly are on vacation so that the system does not generate an alert about them not returning to their home in a stipulated time frame. In relation to sensor installations, it is important that their furniture or home is not damaged or affected. The number of positive notifications linked to different activities of the elderly can lead to a large number of SMSes being received by the relatives, this can lead to a cognitive overload for the relatives and may cause inconvenience even though they would like to know about the wellbeing of the elderly person. In such cases there is a need to have bulk notifications combined into a single SMS which is sent to the relative once in a day. Thus, there has to be a balance in terms of the number of notifications generated for the elderly's activities. A number of issues associated with doors sensors and wall plugs need to be considered and mechanisms created to deal with these, for example how to determine when the door is left open deliberately or inadvertently and when the wall plug is moved from bed-side lamp to sofa-side lamp. Sensor tampering or mobility within the apartment can cause false readings. To check on all these issues needs constant checks and visits to the apartment homes. This brings to light that there is a need for a new form of employment/services such as an IoT janitor or IoT service for maintenance. Lastly, such systems need to be scalable, reliable and cost-effective for widespread adoption.

In conclusion, the provisioning of healthcare for the elderly in their homes/apartments is increasingly essential with the growing elderly population due to the growing stress on the current healthcare resources. In this chapter, we presented the experiences and challenges faced in the deployment and execution of smart-home sensors for healthcare in real apartments where the elderly live alone. The overall feedback received from the elderly and their relatives was positive and they showed interest in continuing with such a system.

In future, in the next phase of the project, we are installing smart home sensors in a larger number of apartments and homes where the elderly live alone within different municipalities across Sweden. Alongside rule-based notifications we will work towards developing and deploying machine learning/AI based techniques to detect abnormal behaviour and generate more types of notifications for all the three key participants in the elderly healthcare domain.

Further, to be able to personalize sensing in homes so that requirements from households with varying needs can be considered, e.g. anomaly detection using artificial intelligence, there is a need to be able to combine arbitrary system installation for sensing in homes while avoiding being locked into verticals of different service providers. This aspect is also considered within our system architecture depicted in Fig. 3, which aims at providing this ability.

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