Internet of Things Controlled Home Objects for the Elderly

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Abstract: The number of elderly people suffering from physical or cognitive difficulty is increasing continuously. Elderly people prefer to live in their familiar environment where they can easily perform different activities of their daily life which is also good for their mental and physical well-being. Internet of Things is a mechanism through which any objects can be monitored, controlled, and manipulated. In order to develop efficient application for the elderly living at home independently, the researcher should be aware of the home objects as well as of the living environment. This study uses systematic literature review to determine applications developed to assist elderly people inside their home. A total of 25 primary studies are identified. With the analysis of those studies, important and relevant objects in the daily life of the elderly are identified. Using the results from the review, a new scenario of home environment is visualized. The visualization is expected to provide caretakers with a better view of the living condition of the elderly and position and state of the home objects. This new home scenario is expected to offer a secure and easy living environment for the elderly, where Internet of Things can be used to control all the frequently used home objects by the elderly.

1 INTRODUCTION

Internet of Things (IOT) is a developing phenomenon in the field of technological advancement as well as in research domain (Atzori et al., 2010; Xu et al., 2013). The main principle of IOT is continuous monitor and control of everyday objects or things over the internet. The thing in IOT has no limitation and can be any objects that are used in day to day life (Bassi and Horn, 2008). The thing can be any living or non-living object; from electronic devices to foods, clothes and furniture we use in our daily life, from animals like cow, dog, cats, and rats, to plants and trees (Madakam et al., 2015). An object or thing has its own unique identity, which allows communication between not only humans, but also between objects (Madakam et al., 2015). With availability of continuous internet connection, all the connected objects can be monitored regularly through an interconnected network.

Over 7% of the world population are over 65 years of age and the number is expected to increase 20% by the year 2050 (Morris et al., 2013). Also, by 2035, the number of people affected by dementia is expected to double. Hence there is requirement of policies and resources to meet the need of the aging population as well as of those suffering from dementia. Elderly can live longer and safer if they stayed in their own home environment (Bassi and Horn, 2008). Their friends and family also feel secure to have them in their own house in comparison to hospitals and care homes (Arcelus et al., 2007). Hospitals and healthcare centres may not be able to provide services to all who require (Arcelus et al., 2007). Smart homes can provide automation of domestic tasks, easier communication, higher security, and are adaptive to modern human needs as well as social needs (Morris et al., 2013; Lê et al., 2012).

The aim of technological advancement for elderly is to provide them a sense of independence even if they are physically or cognitively incapable. Avoiding diseases and encouraging healthy living is also a prime concern (Tran, 2002). Everyday activities that are easy to accomplish can be problematic as people get older. Simple tasks like brushing teeth, turning the tap off, switching TV off or on, and taking medicines can get tougher with age (Morris et al., 2013). IOT is a step forward in helping elderly complete these activities without physical presence of a caretaker, which also helps to minimize their expenses (Arcelus et al., 2007). IOT will also help one caretaker to monitor and assist multiple elderly patients from a remote location. With IOT, caretakers have the freedom to

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manipulate the home objects themselves and control them.

Above mentioned concerns motivated us to conduct a study to find different IOT based applications targeted for the elderly people living alone. Moreover, the goal of the study is to determine different kinds of home objects dealt in those applications. Figure 1 shows the overall idea of the study. This study is beneficial for those researchers and developers who are using IOT for the care and well-being of the elderly. The paper is structured as follows: section 2 presents an overview of previous studies. Section 3 explains the research method carried out for the study, and section 4 presents the findings of the study, limitation of the study, and scope for future research. Section 5 concludes the paper highlighting the main contribution of our work.

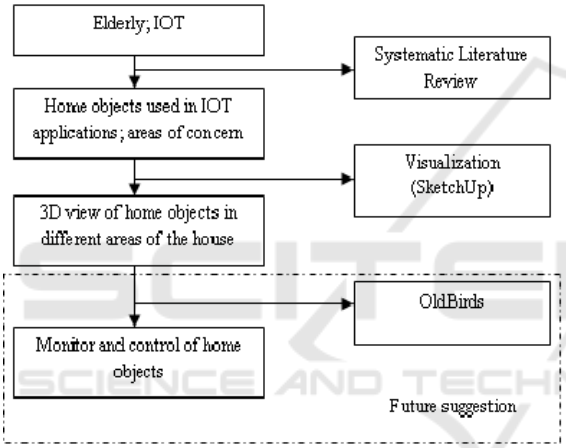

Figure 1: Overview of the study.

2 RELATED STUDIES

This section discusses about IOT and its all-round effectiveness. Furthermore, it accentuates some studies that highlights importance of IOT based applications for the elderly.

2.1 Internet of Things

IOT shows us a world where anything can be connected to any other thing. With embodiment of sensors and actuators in various physical objects, ranging from roadways to pacemakers, an object can both sense the environment and communicate. Information about the objects can be retrieved faster with IOT and people can make wise decisions quickly (Bassi and Horn, 2008). IOT enables inter-connectivity of different objects through a global infrastructure, internet (Madakam et al., 2015). IOT have been used successfully in various fields such as assisted living, e-health, domotics, enhanced learning, surveillance, environment monitoring, health monitoring, critical infrastructure monitoring, etc. (Atzori et al., 2010; Gubbi et al., 2013).

The main strength behind IOT is that using interconnected devices, it can have high impact on several aspects of our everyday life (Atzori et al., 2010). Considering the increasing number of research on IOT in recent years (Stankovic, 2014), it can be expected that IOT will play a greater role in our daily lives in upcoming years. IOT can help in digitalization of day to day activities, providing security in buildings, and decreasing the energy consumption of devices. IOT is not an independent system, but it can be regarded as a critical, integrated infrastructure by the use of which many applications and services can operate (Stankovic, 2014).

2.2 IOT and Elderly

As people grow older, their social circle and frequency of communication decreases on a regular basis. It can be caused by loss of family members or friends, diminishing eyesight or hearing ability, cognitive impairment, memory loss, etc. (Touhy and Jett, 2013). Moreover, their relatives and family members live far from them. It leads to a sense of isolation that may impact mental as well as physical health (Vardoulakis et al., 2012; Williams et al., 2014). The loss of physical as well as cognitive abilities affects their day to day activities and they require assistance in completing their daily tasks.

The introduction of IOT in the life of elderly people can help monitoring of chronic illness, on demand provision of fresh food, sending alarms and reminders, and enabling communication with family, friends or health care professionals (Dohr et al., 2010) as depicted in figure 2. Reminders of stove or iron left on, alerts at front door about visitors or intruders at home, etc. can be helpful for physically and cognitively disabled elderly people (Lê et al., 2012), but with IOT this service can be improved since required action can be taken by the caretaker remotely.

A caretaker can assist an elderly in completing tasks inside as well as outside their home environment for instance, guiding the elderly citizens to directions where they need to go (Firouzian et al., 2015). The concerns about privacy and security arise when we consider helping elderly in their home environment. Video monitoring is often regarded as an invasion to privacy by the elderly (Arcelus et al., 2007; Beunk,

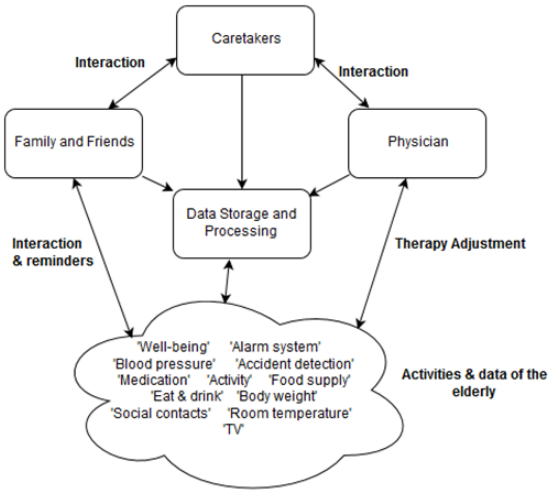

Figure 2: IOT and elderly, based on (Gubbi et al., 2013).

2015). To ease this concern, Old Birds, a web application prototype was implemented (Korvala and Raappana, 2015). It is run by a game engine that was originally built for remote care giving (Pulli et al., 2012). The elderly and their surrounding environment are presented in gaming avatars, which helps to minimize the concerns of privacy, as shown in figure 3.

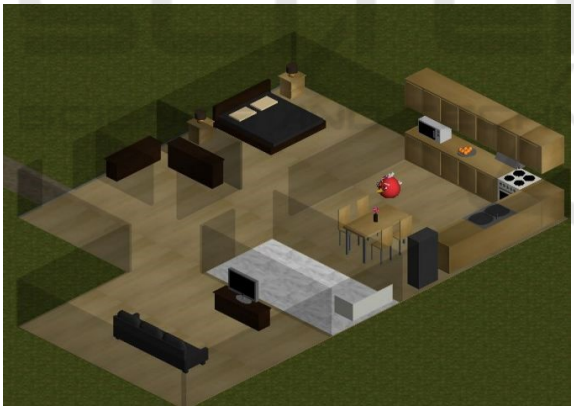

Figure 3: Old Birds simulation environment, (Firouzian and Nissinen, 2013).

Currently, one of the main challenges for IOT system designers is to design a system that can help elderly in everyday activities as well as be supported by health care workers (Bassi and Horn, 2008). This rapid shift of the need of medical services for in-house care (Lee et al., 2013) provides the developers of IOT based applications with a new and productive area to deal with. Daily monitoring is enhanced by IOT thus increasing the quality of life and health of elderly people (Tran, 2002; Yang et al., 2014).

3 RESEARCH METHOD

This section explains the research method utilized in this study. Systematic Literature Review (SLR) was selected as a research method, which is a means of identifying, evaluating, and interpreting all research relevant to the particular area of interest or research question (Kitchenham, 2004). SLR can be used to verify or contradict any research hypothesis and can also lead to new research activities (Kitchenham, 2004; Biolchini et al., 2005).

The steps followed in the SLR were based on the guidelines for conducting a SLR (Kitchenham, 2004; Kitchenham and Charters, 2007). SLR, in general, is more time consuming than other traditional reviews and provides information about the effects of some phenomenon across a wide range of settings and empirical methods (Kitchenham, 2004). The first step in SLR is the formation of the research protocol. After a research area or a topic is finalized, it is necessary to create a review protocol that consists of research questions, inclusion and exclusion criteria, quality assessment criteria, keywords used to search literature, steps for reviewing the literature, and designated synthesis of the findings (Kitchenham, 2004; Biolchini et al., 2005).

The following two research questions were selected for the study:

- RQ1: What are the different areas inside the house where IOT can be applied for the elderly?
- RQ2: What kind of home objects necessary for the elderly are controlled by IOT based applications?

The inclusion and exclusion criteria used for the review are presented in table 1. Along with those, following quality assessment criteria were created to select the primary studies that were as relevant to the research questions as possible:

1. Is the application discussed in paper targeted to old people living alone?
2. How much is IOT discussed as part of everyday life for the user?
3. Was the application an experiment, controlled observation study, observation study without control groups or just theoretical?
4. Does the study clarify the problems faced during implementation?
5. Does the study provide details of the objects controlled by the applications?
6. Does the study is concentrated in daily activities inside the home or outside.The labels consists of sequential numbers?

Table 1: Inclusion and Exclusion criteria.

Inclusion Criteria	Exclusion Criteria
• it covers the areas of both IOT and elderly citizens • at least one home 'thing' is controlled remotely • focus on elderly or elderly people with dementia • it is a journal (peer reviewed), conference article, chapters from a book or a doctoral dissertation	• it is about IOT focused on all age group • it is not in English • it is a presentation • it is a technical report • it presents an incomplete project • it is theoretical information only • it covers IOT but not elderly assistance • it covers elderly assistance but not IOT

The use of inclusion and exclusion criteria along with the quality assessment criteria was completed following the steps shown in figure 4.

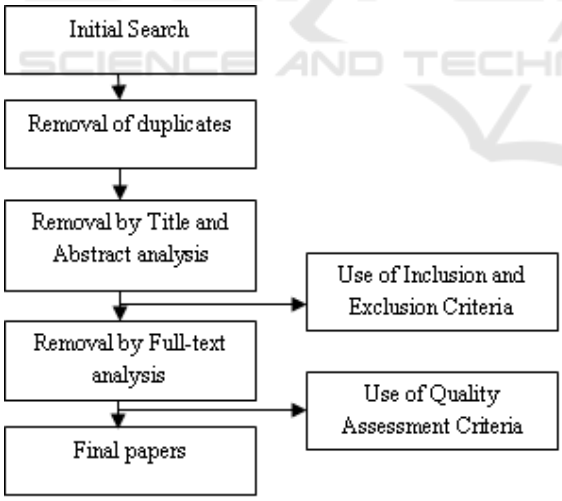

Figure 4: Steps to select primary studies.

4 RESULTS

This section discusses the findings of the SLR and relates the data to the research questions. Limitations of the study and scope for extending the research are also pointed out.

4.1 Findings

A total of 229 papers were identified in five different databases; Scopus, IEEE Xplore, Science Direct, Web of Science, and ProQuest. Following the steps presented in figure 4, a total of 25 papers were identified as the final selection of primary studies, which makes around 11% of the initial collection of papers. Among the 25 studies, 15 were conference proceedings paper, 8 were journal articles and 2 were monographs. Each of the studies explained applications that were developed to assist the elderly, make their life easier,improve their health, and take care of them in emergencies.

It was observed that most of the applications focused on the health aspect of the elderly.Body sensors were the most implemented sensors with applications in 11 of the 25 papers utilising it. Ambient sensors were second, with fall detection a common area of concern as well. Applications also dealt with providing proper medication to the elderly and maintaining a healthy lifestyle like guiding them in exercising. Table 2 lists the areas of the focus for the study and the number of paper that dealt with that area.

Table 2: Areas of Concern.

Areas of Concern	Number of Papers
Kitchen	7
Health Care	22
Dining room	1
Living room	6
Bedroom	4
Bathroom	3
Shopping	1
Social connection	2
Security	4
Training and gatherings	1
Job Search	1
Exploration	1
Study room	1

Table 3 lists all the home objects that were identified in the applications dealt in the primary studies. There were some studies that did not clearly indicate the objects controlled by the application, as they were denoted as smart objects or as devices in the house, and have been excluded.

4.2 Visualization

Most of the time, caretakers may not know the environment of the elderly well enough (Ikeda et al., 2011). With visualization of IOT objects, a caretaker

Table 3: Home objects used in IOT applications.

Objects	Corresponding Paper
Kettle	(Brereton et al., 2015)
Mobile phone	(Dohr et al., 2010; Fortino et al., 2015; Gomes et al., 2015; Tang et al., 2015; Laranjo et al., 2013; Panicker and Kumar, 2015)
Blood Pressure meter	(Dohr et al., 2010)
Body sensors	(Fortino et al., 2015; Gomes et al., 2015; Guo and Bai, 2014; Dagale et al., 2015; Liang, 2016; Panicker and Kumar, 2015; Savola et al., 2015; Zgheib et al., 2015; Raad et al., 2015; Sung and Chang, 2014; Chen et al., 2015)
Ambient sensors	(Gomes et al., 2015; Luo et al., 2012; Boric-Lubecke et al., 2014; Wu et al., 2013; Savola et al., 2015; Zgheib et al., 2015; Rusu et al., 2015)
Gas	(Gomes et al., 2015; Lee, 2015; Cunha and Fuks, 2015)
Lights	(Gomes et al., 2015; Tang et al., 2015; Cunha and Fuks, 2015; Neßelrath et al., 2011; Zgheib et al., 2015; Rusu et al., 2015)
Exhaust (Smoke)	(Gomes et al., 2015; Lee, 2015)
TV	(Konstantinidis et al., 2015; Lee, 2015; Wu et al., 2013; Neßelrath et al., 2011)
Medicine bottle/drawer	(Laranjo et al., 2013; Cunha and Fuks, 2015; Neßelrath et al., 2011; Sohn et al., 2015)
Tablets	(Laranjo et al., 2013)
Camera	(Lee, 2015; Rusu et al., 2015; Sohn et al., 2015)
Food drawer	(Lee, 2015)
Chair/ Sofa	(Liang, 2016; Wu et al., 2013; Zgheib et al., 2015)
Bed	(Liang, 2016; López-de Ipiña et al., 2010; Wu et al., 2013; Zgheib et al., 2015)
Temperature sensor	(Cunha and Fuks, 2015; Rusu et al., 2015; Sung and Chang, 2014; Chen et al., 2015)
Humidity sensor	(Cunha and Fuks, 2015; Chen et al., 2015)
Infrared sensors	(Cunha and Fuks, 2015)
Noise sensors	(Cunha and Fuks, 2015)
Shoes	(Wu et al., 2013)
Door	(Wu et al., 2013; Savola et al., 2015; Rusu et al., 2015; Chen et al., 2015)
Oven/Microwave	(Wu et al., 2013; Neßelrath et al., 2011)
Electricity meter	(Tang et al., 2015; Wu et al., 2013)
Kitchen Surface	(Neßelrath et al., 2011)
Fridge	(Neßelrath et al., 2011)
Dishwasher	(Neßelrath et al., 2011)
AC	(Neßelrath et al., 2011)
Switches	(Zgheib et al., 2015)
Window	(Rusu et al., 2015)
PC	(Sohn et al., 2015)
Weight scale	(Sung and Chang, 2014)

can know the status of the objects continuously and determine the changes in the state of the object due to any activity of the elderly. With such visualization, presence of camera is also redundant which will encourage old people to accept the technology as they regard technology, mainly video surveillance, as an intrusion to their privacy (Arcelus et al., 2007).

Visualization is a method to infer new knowledge from collected information to get a comprehensive view of the space of interest (Gershon and Eick, 1997). The home objects from table 3 were thus utilized to vision a scenario in the day of an elderly person. This visualization is intended to showcase an elderly person in different areas of the house and show different IOT enabled home objects that they have to deal with for their daily activities. The areas of the house where elderly require assistance from the caretakers were selected as: bedroom, living room, kitchen, dining room, and bathroom.

The visualization will help the caretaker to deter-

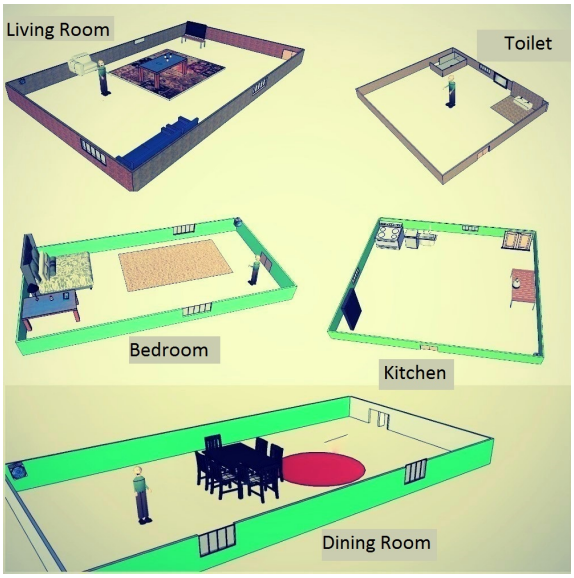

Figure 5: Visualization of different areas of the house.

mine the location of the elderly in the house and observe their actions. The caretaker can monitor the intake of medicine by analyzing weight of the medicine pill bottle, and provide notifications via smart phone or TV to take the medicine when necessary. Also, ambient sensors are enabled across all the rooms of the house to determine sudden emergencies like falling down. Wearable sensors will help to continuously monitor the state of health of the elderly and take action in case of sudden bodily changes. The home objects that are controlled by the above mentioned scenario are listed in table 4.

Table 4: Home objects in the visualized scenario.

Bed	Lamp	Mobile
Pill Bottle	Door/Windows	Chair
Stove	Dishwasher	Sink
Kettle	Fridge	TV
Food Cabinet	Table	Sofa

4.3 Limitation and Future Scope

The main focus of the study is limited within the perimeters of the house of the elderly. The research can be extended by including the applications that are designed to assist elderly people outside their home. Since areas for use of IOT is quite large, future research can be done by including applications that have been designed not just for the elderly but for people of all age group. This will help to determine various other areas of concerns and home objects.

The data from SLR indicates that application developers consider health care as the major area of concern. For future applications, not just health care, but other aspects such as security can be integrated into the existing system, as shown in the visualization section. Also, there is a need of an IOT application that helps not only assisting when necessary but also constantly monitoring different parameters of their health. For e.g. a caretaker can monitor stress level or heart beat rate of an elderly while giving them instructions on how to cook a meal. The data from SLR and our visualization ideas both can be utilized to create a simulation of the home environment of the elderly.

The inclusion of scientific studies only in the review process leaves out many newspaper articles, electronic sources and other archives. It can be possible that all the IOT enabled applications designed for the elderly might not have been discussed in scientific literature. Future researchers are encouraged to include other sources as well, to broaden the range of application search.

5 CONCLUSION

The main contribution of this study is to provide the information about existing applications for the elderly in the context of their areas of concern and home objects controlled by them. The aim is also to visualize a new scenario of IOT enabled home environment for the elderly. Existing research have either focused on IOT, or some particular areas like health care or socializing. The visualization scenario integrates different areas of concern for the elderly and provide some data for the researchers as well as developers.

This study dealt with in-house environment only. Since elderly people spend most of their time inside their house, it is necessary to know about the objects they use regularly in order to create an autonomous environment for them. The data from SLR can be further utilized to develop new applications to improve quality of life and health of the elderly inside their home environment. These applications can help to assist elderly in their daily activities through technological assistance and also monitor them regularly.

The study also presents a 3D visualization of a safe and secure living environment across different areas of the house including the home objects. This can be utilized by application developers as a baseline to develop IOT based applications for the elderly. The visualized scenario is helpful for caretakers in monitoring and assisting the elderly.

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