A Wearable Sensor Based Elderly Home Care System in a Smart Environment

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Abstract— **Elderly people need 24-hours care and support for their physical disability and mental weakness. With the ever growth of the elderly people this section needs some importance. But 24-hours caring and monitoring can't be provided by the family members and caregivers because of their daily affairs. So the question arises here how they gives supportive care to their elderly. The answer is related to the using technology. In every sphere of our life technology is used for making the life easier and comfortable. So the caregivers monitor and care their elderly people with the help of technology. These kind of technologies introduced smart environment. The smart environment informs the caregivers about the current position and status of the elderly people and their living environment. In this paper we introduced a wearable sensor based elderly home care system in a smart environment. We have used personal computers as monitoring system, sensors for sensing data, webservice to communicate between monitoring systems. From our user study we can see that our system is not only useful but also would be helpful for further research in this domain.**

Keywords—elderly care; smart environment; wearable sensors.

I. Introduction

Technology related to the computer science is widening in each and every field. It is a part and parcel of our life. Young generations are greatly blessed with the computer science related technology. But the aged people such as 65+ peoples are less associated with this kind of technologies. From a recent studies [3] researcher mentioned that the increasing rate of elderly population is 7.9% of total elderly people in 1950 which is projected to rise as high as 16.2% in 2050 throughout the world.

If we can make an interaction between elderly people and the technology their life will be better and more independent. The rapid growing of elderly people and ensuring their expected independence and security are great challenges to the family members and caregivers. By the way the family members and caregivers of the elderly people have a personal career such as job, study, social community etc. In spite of their intention of staying with their elderly people all the time, they are not able to do that for their daily affairs. If there is a chance to take care of the elderly people remotely then it will be great for both caregivers and elderly. For this aspect technology related to the computer science is a solution

Sensor based elderly home care system in a smart environment is not a new concept. Many researches already developed in this area. The elderly people are bound to go to the costly clinical institutions for the safe residential purposes where they can receive consistent medical observation. But the problem is all about economical, because the services of those clinical institutions are quite good. As the cost of those medical institutions is huge, the general elderly people cannot afford to maintain the cost for the long time. So a smart home cares that monitor elderly people's health and welfare as like as those clinical institutions. The home care system would provide elderly people more satisfied and autonomous behaviors and habits as well as more nominal care [2] [5].

In paper [4][8] the researchers presented a smart home system for the elderly, developed by the technology assisted friendly environment integrated in the system and develops a framework for the processing and communication of the extracted information. Advance in sensor and network technologies have made these possible. A smart home which is a residence equipped with smart technologies providing services that enhance human way of living i.e. safety, security, entertainment, etc. would allow elderly to maintain living independently in their homes and still in control of their healthcare cost and status. There is a fall alert option which is measured with the posture that is recognized programmatically and image graphical representation. Whereas the prototype that design is consists of multiple nodes embedded with camera [10]. Tele-health is a wide-ranging span that used to denote to the facility of health care where both the use of electronic data and telecommunications machineries backing long-distance clinical health care, patient and professional health management activities [7][12]. Tele-health permits for such things as distant doctor-patient meetings, remote monitoring [1] and health education services. Few specific parameters of a patient can be penetrated, and then warnings are processed towards expected health care specialists via

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internet gateway [9]. The smart phone is basically is connected to the personal computer using the TCP/IP method through Wi-Fi [1] [6].

Quynh Lê et. al. [6] detected the present condition of elderly such as falls, heart attack and stroke etc. If the caregivers rescue them within an hour, there is a chance to survive.

II. Proposed System Architecture

In this section we will describe the architecture of the proposed system. At first we will discuss about the overview of our proposed system. Then we will discuss the functionality of different modules of our system.

There are two modules in our system such as the main module and the wearable user module. The main module is the central monitoring system which is installed in the user's room. The user module is wearable. The components of this module is carried by the user and attached with the user's body. The wearable module passes information of user to the main module via a web service. The web service is running on a remote hosting in the internet. So there is no matter of the distance between the main module and wearable module.

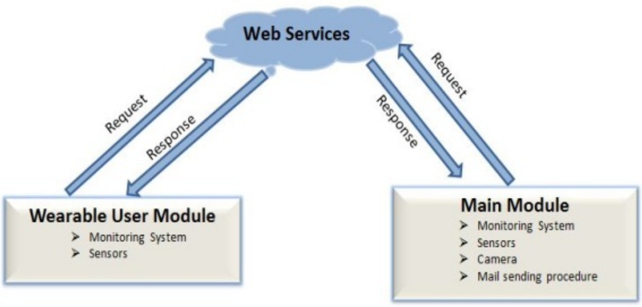

Figure 1: Proposed system architecture. The wearable module and the main module are sharing the information to or from the web service that is located in the Internet.

A. *Wearable User Module*

There are several components in the wearable user module such as sensor belt (contains different sensors like accelerometer, IR-distance, light, temperature and Humidity sensors etc.) which is attached with the user's body, a sender personal computer (pc) in which sensors of the sensor belt passes raw sensing values. Then the system running in the sender pc process the raw sensing value and calculates the user activities and status. The system has a web service reference. The architecture of the user module is shown in the **Figure 2.**

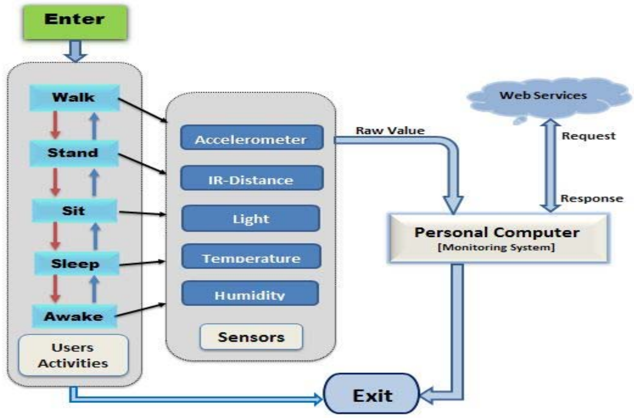

Figure 2: Wearable user module. The array of sensors is connected with a monitoring system and processes the sensor data and finally sends the processed data to the main module through the web service.

The sensing value of the sensors fluctuates by user's movement. Each and every time when value changes the monitoring system takes the raw value and processes the value to calculate a specific result. The user module is able to calculate every activities and status of the user and the result is in the form of string such as "User Status is OK", "User Causes a Fall Down", "User is Walking" etc. Based on the calculated results the system sends a specific integer to the web service. That's the output of the wearable user module.

B. *Main Module*

In the main module (**Figure 3**) several sensors such as Touch, Light and IR Distance Sensor are connected to provide services to the user module. The sensors are situated at different position of the residence of the user. The sensing value of the sensors fluctuates if the environment and obstacles of the residence change. When the value of the sensor fluctuate it passes the changed value to the central monitoring system and the system running on the main module process the raw sensing value and produces results based on processed value. There are a photo capture and mail sending procedure in the system of the main module. When new results are generated a new photo of the residence is taken by camera.

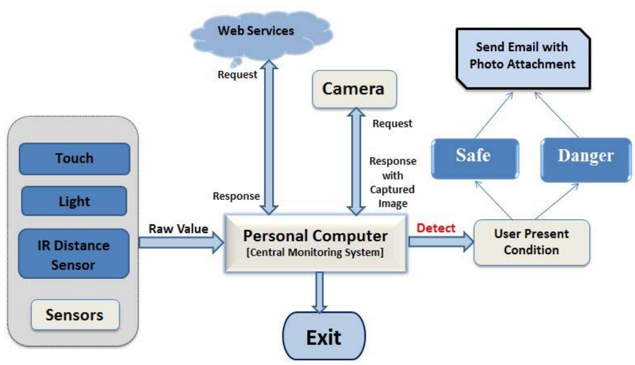

Figure 3: Main module architecture. The array of sensors is connected with a central monitoring system and processes the

sensor data and finally combines the processed data from main module and user wearable module through the web service.

The main module processes the inputs and produces two types of output based on the inputs. One type of output is user status and activities and another type is about condition of room. The outputs are combined together and a combined result is produced. Then the combined result is send as a string parameter to the mail sending procedure. The mail sending class sends the mail to the user's caregivers with a photo attachment taken by the photo capture procedure with a camera. By this way the caregivers of the users are updated with the current information of the patient.

C. System Flowchart

The data flow of the proposed system is presented in **Figure 4.** According to this flow chart the monitoring system extract data from wearable sensors, then process the sensing data to produce results then send a value corresponding to the results to web service. At the start of the main module, the monitoring system extract data from sensor and get response from web service if any request made. Both data are the processed and produced as results. Then the results are combined and send to the caregivers as a final output of the system.

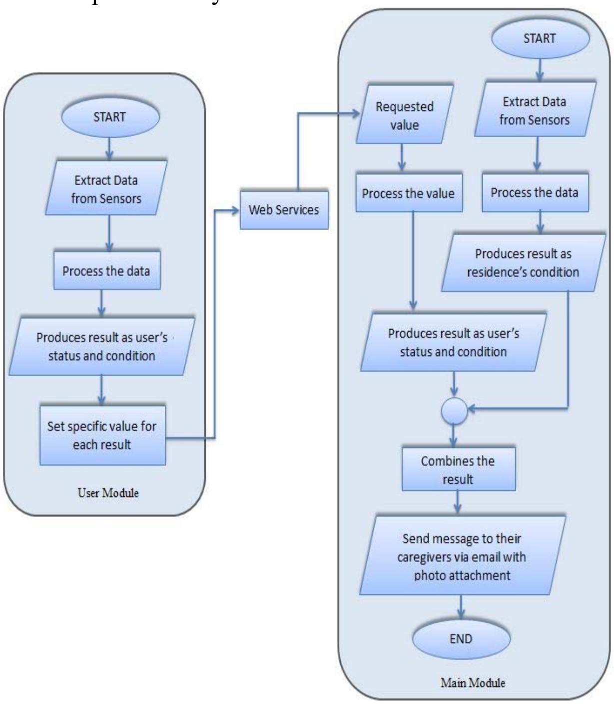

Figure 4: Flowchart of the proposed system. The array of sensors processes the sensor data and finally sends the processed data to the main module through the web service.

III. Implementation and Result

This section describes the implementation details of the prototype that reflects the proposed elderly home care system presented in Section II. The prototype integrates the main three modes of interaction, i.e., wearable user module, web service module and the main module. Microsoft C# version 8.0 and the Phidget API [11], ASP.NET web services, Microsoft Quick Cam and a core i5 with 4GB RAM laptop were used to develop the prototype system. In the following, Section III-A describes the experimental setup and the different devices that are connected within the environment, while Section III-B discusses the result produced by the prototype system.

A. Environment Setup

This section describes the experimental setup that we conducted in our laboratory environment. The motivation of our experiment was to produce a data set so that we can work on the dataset to determine the performance of our proposed approach. **Figure 5** shows the interface kit and sensory devices (accelerometer, IR distance sensors) combo that were placed in the user body. The accelerometer sensor placed is the user belt in way so that it can determine the user position (**see Figure 6**) such as standing, sitting, lying, squatting etc. The 3-dimentional accelerometer values changes when the user moves from one position to the another, the system always track the changes and when cross a predefined threshold values then it trigger the controlling system to pass a message to the main module through web service.

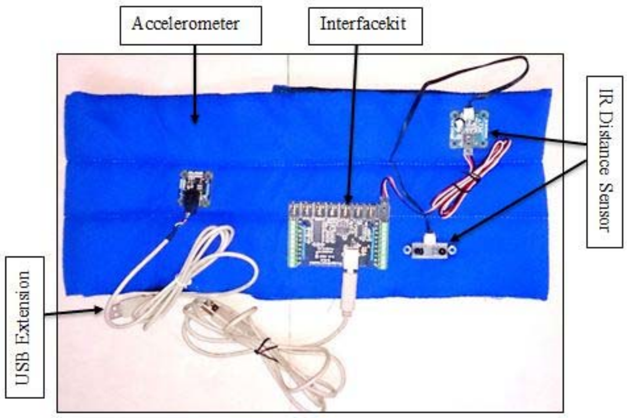

Figure 5: Sensor belt with different sensors of the wearable user module

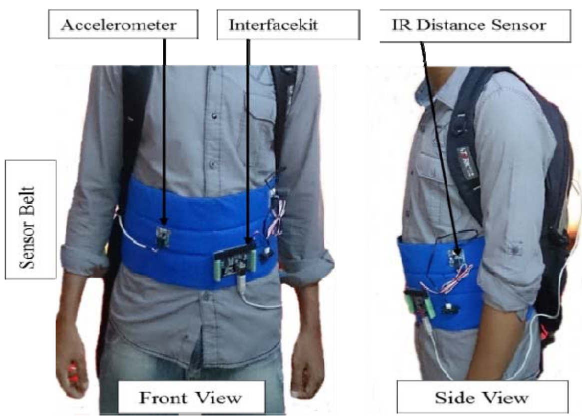

Figure 6: User with wearable user module in different view.

At side view we can see that the interfacekit is connected to the monitoring system of the user module via a USB extension.

The main module is installed in the living room of the user that includes light sensors, IR distance sensors, touch sensors, a camera and personal computer as well as the monitoring system. The sensors are connected to an interfacekit and interfacekit is connected to the main module via a USB extension. The light sensor detect the lighting condition inside the room, the IR distance sensors used to measure the distance between the user and the camera so that it can change the camera focus and capture the environment image smoothly. Moreover the distance sensor is used to identify the position of the user inside the room. We used two different IR distance sensor in our prototype one is short range (Sharp IR distance sensor which has 10cm ~300cm capacity) and medium range (LHT-9-45 Mid-Range Infrared Distance Sensor which has 1m~10m capacity which is enough for any standard size room). Touch sensors is placed on the bed, sofa or char and send a positive signal when user touch the sensor i.e. when will sit on the sofa or lying on the bed etc. The Components of the main module is presenting in **Figure 7**.

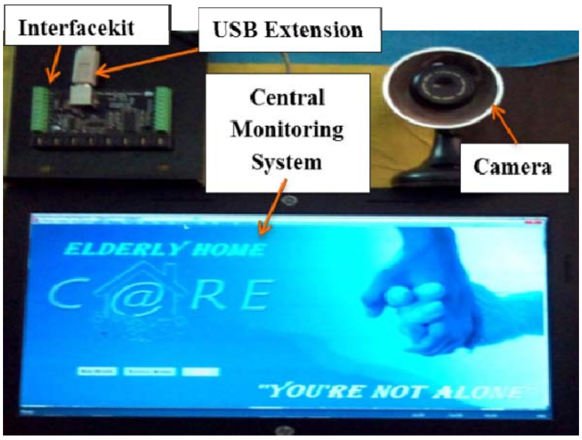

Figure 7: Components of the main module.

B. Results

The goal of our evaluations is to determine the performance of our elderly home care system. We experimented on different user's activities to measure the detection capabilities of our prototype. Different types of user's activities are shown by the **Figure 8.** In the following section B-i we will present the prototype performance and in section B-ii we will present the user study.

Figure 8: User Activities (a) user status: ok (b) user status: fall down (c) user status: danger falls down.

i) Response Time

We calculate the response time of all the sensors to our system in different categories. In the program we placed some timer to identify the processing time and finally placed recorded time on a graph as shown in the **Figure 10.**

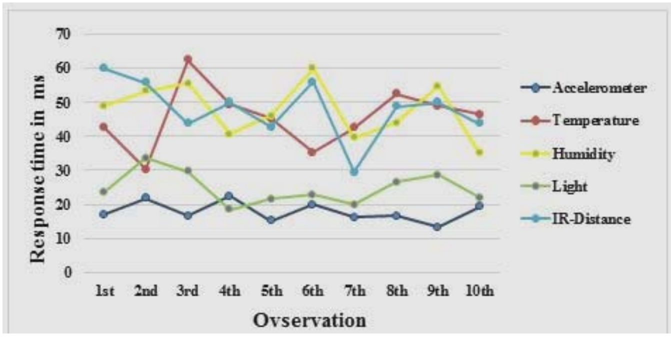

Figure 10: Response time of the sensors of wearable user module.

Response time of our system largely depends on 3 major steps. They are:

- Detection time of user activities; it depends on the response time of the sensors, represented by ***U(t).***
- Communication time between wearable user module and main module via web service, represented by ***W(t).***
- Mail delivery time, represented by ***M(t).***

Now, if response time is ***R(t)***, then the equation is:

$$R(t) = U(t) + W(t) + M(t). \qquad \textbf{Eq (I)}$$

We calculate the total response time based on detection time, communication time and mail delivery time. We measured the detection time of user activities, communication time between two modules and mail delivery time. We measured total 10 times and the result is shown in **Figure 11.** The value of ***M(t)*** depends on the bandwidth of the internet connection and the SMTP server current job in his queue. If the bandwidth is slow then mail delivery requires long time. According to our test we found average mail delivery time was 1285ms. The average detection time and communication is 37.469ms and 388.8ms respectively. Overall average response time is 1711.296ms.

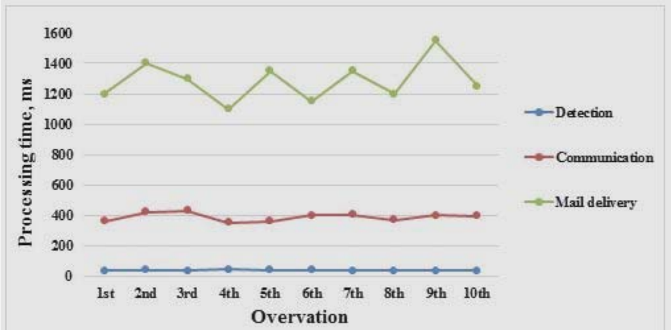

Figure 11: Processing time of different modules.

According to the **Figure 11** the response time of system is largely depend on the mail delivery time. If high bandwidth is available then the performance will be increased a lot.

v) Usability Analysis

Prior to conducting the usability test we designed a test plan, where we defined our evaluation objectives, developed questions for the participants, identified the measurement criterion and decided upon the target users of the system. Two different type of qualitative measurements are performed for both old persons and caregivers. As they both used the system and complement each other, it was necessary to evaluate prototype from both perspectives. The test took place in our university laboratory with 10 volunteers (old persons) comprising different age groups. Six of the participants were in the age group 1 (age 65-68), three of them were in the age group 68–71, and the remaining one were in the age group 71+. These old persons were found through local old age home and known people. They had different kind of disabilities: two persons have low eyesight and one has a hearing problem. We also provided four more known professional people (three female and one male) as caregivers who were with them the whole time. For complexity reduction the old person stayed with the system only at day time from 11 am to 5 pm each day. Each subject stayed for four days in our experimental room. Initially, the volunteers were asked to wear the wearable user belt to their belly. The users were permitted to access the system in the test environment for a week.

#	Question
Q1	Proposed system is acceptable
Q2	The system is easily adaptable
Q3	The system can harm daily affairs
Q4	Response rate is satisfactory
Q5	Consider using the system in your daily life

Table 1: Questionnaires to the user.

The users' activity was monitored throughout the experiment and recorded for analysis. Later, based on their interaction experiences, the users completed a questionnaire (listed in **Table 1**), where they were requested to provide ratings for the acceptability, adaptability, harmness, satisfiability, and ease of use of the system. The user responses are shown in Likert Scale [13] in **Figure 12**. The ratings of the questionnaire were in the range of 1–5 (the higher the rating, the greater was the satisfaction). The average of the responses of the users were calculated in percentage form and measured after the usability tests.

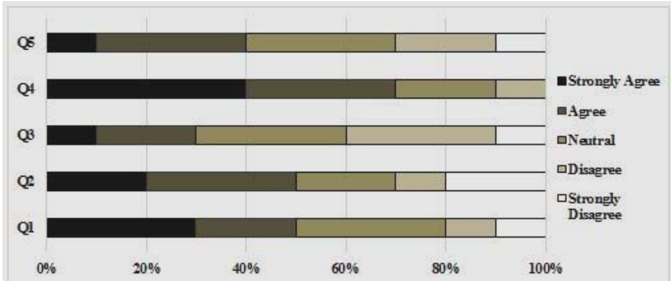

Figure 12: Usability study based on the questionnaires listed in Table 1.

If the answers are "strongly agree" or "agree" for the question Q1, Q2, Q4 and Q5 then the answer is taken as positive response. If the answers are "strongly disagree" or "disagree" for the question Q3 then the answer is taken as positive response. We count the positive response for each question. Then we compare the responses between the users of different gender and the users of different age groups. The positive responses of the each question are shown below. It is worth mentioning that the percentage of positive responses for the question Q1 to Q5 is 50%, 50%, 40%, 70% and 40% respectively of total users.

At first we compare between the male and female participants. The comparison is depicted in the following **Figure 13**. From the figure we can see that male user give more positive response than female users. Then we compare between participants of different age groups. The comparison is depicted in the following **Figure 14**. From the figure we can see that more positive responses are from the participants of group-1.

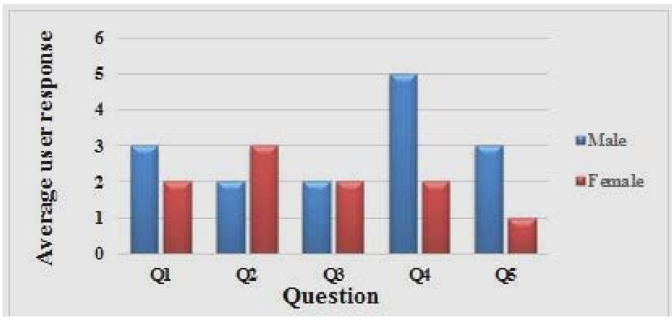

Figure 13: Comparison of the positive responses between users of different gender.

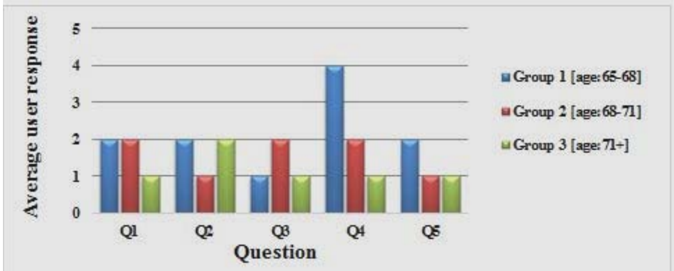

Figure 14: Comparison of the positive responses between users of different age group.

V. CONCLUSION

Most of the advanced technological futures are for the young people. But as we early discussed the percentage of the elderly people is increasing day by day. In this paper we proposed a home care system in a smart environment for the elderly people. We presented the implementation details of a preliminary prototype as per the requirements. Finally, from our usability study we received suggestions from both old people and the caregiver to improve the prototype like add video feed so that the caregiver can see what exactly happen in the monitoring environment. In the future we want to incorporate more sensors in a real assisted living environment to provide intuitive interaction capabilities to the user in order to effectively control the entertainment. We also plan to involve more users in the test in realistic settings. Moreover in future we will incorporate to make the wearable user module will be embedded and there will be a phone call or sms based service to inform caregivers about their elderly people. We believe that the proposed approach for elderly remote home care framework will introduce a new direction in smart home domain.

References

[1] Jer-Vui Lee, Yea-Dat Chuah and Kenny T.H. Chieng, “Smart Elderly Home Monitoring System with an Android Phone ”, *International Journal of Smart Home*, Vol. 7, No. 3, pp. 17-30, May- 2013.

[2] Amaya Arcelus, Megan Howell Jones, Rafik Goubran and Frank Knoefel, “Integration of Smart Home Technologies in a Health Monitoring System for the Elderly” IEEE, *21st International Conference on Advanced Information Networking and Applications Workshops (AINAW’07)*, Universidad de Malaga, pp. 1-4, 2007.

[3] Saisakul Chernbumroong, Anthony S. Atkins, and Hongnian Yu, “Perception of Smart Home Technologies to Assist Elderly People”, *The 4th International Conference on Software, Knowledge, Information Management and Application (SKIMA 2010)*, Paro, Bhutan, pp. 1-5, 2010.

[4] A. Gaddam, S.C Mukhopadhyay and G. Sen Gupta, “Development of a Smart Home for Elder-People Based on Wireless Sensor”, *Lecture Notes on Electrical Engineering, Smart Sensors and Sensing Technology, ISSN 1876-1100, ISBN 978-3-540-79589-6 Springer-Verlag*, pp. 361-380, July 2008.

[5] Ali Maleki Tabar, Arezou Keshavarz and Hamid Aghajan, “Smart Home Care Network using Sensor Fusion and Distributed Vision-based Reasoning”, *VSSN’06*, Santa Barbara, California, USA, pp. 145-150, October 27, 2006.

[6] Quynh Lê, Hoang Boi Nguyen and Tony Barnett, “Smart Homes for Older People: Positive Aging in a Digital World”, *Future internet 2012*, Vol. 4, pp. 607-612, 19 June 2012.

[7] S.P. Pande and P. Sen, "Review On: Home Automation System for Disabled People Using," *International Conference on Advances in Engineering & Technology – 2014 (ICAET-2014),* pp. 76-78, 2014

[8] Jessica Cocco, “Smart Home Technology for the Elderly and the Need for Regulation”, *Journal of Environmental and Public Health Law*, Volume 6-Isssu 1, pp. 85-108, Winter 2011.

[9] Vivian Vimarlund, Nils-Göran Olve, Isabella Scandurra and Sabine Koch, “Organizational effects of Information and Communication Technology (ICT) in elderly homecare” *Health Informatics Journal (14)*,Vol. 3, 2008.

[10] Arezou Keshavarz, Ali Maleki Tabar, Hamid Aghajan, “Distributed Vision-Based Reasoning for Smart Home Care”, *ACM SenSys Workshop on Distributed Smart Cameras (DSC’06),* 2006.

[11] Phidgets Inc., “http://www.phidgets.com” Last visited: 20th July

[12] GlobalMed, “http://www.globalmed.com/additional resources/telehealth-telecare-and-telemedicine-whats-the-difference.php”, Last visited: 23th July 2015.

[13] Likert R (1932) A technique for the measurement of attitudes. Arch Psychol 140:1–55

.

[14] Anwar Hossain, M., Atif Alamri, and Jorge Parra. "Context-aware elderly entertainment support system in assisted living environment." In *Multimedia and Expo Workshops (ICMEW), 2013 IEEE International Conference on*, pp. 1-6. IEEE, 2013.

[15] Hossain, M. Anwar, Atif Alamri, Ahmad S. Almogren, S. K. Hossain, and Jorge Parra. "A Framework for a Context-Aware Elderly Entertainment Support System." *Sensors* 14, no. 6 (2014): 10538-10561.

[16] Hossain, M. Shamim, SK Alamgir Hossain, Atif Alamri, and M. Anwar Hossain. "Ant-based service selection framework for a smart home monitoring environment." *Multimedia tools and applications* 67, no. 2 (2013): 433-453.