Smart Home: Recognition of activities of elderly for 24/7; Coverage issues

Anindya Nag and Subhas Chandra Mukhopadhyay

School of Engineering and Advanced Technology
Massey University (Manawatu Campus)
Palmerston North
New Zealand

Abstract

A smart home has been designed and developed to monitor elderly people who lives alone and needs assistance to perform their daily living activities. The system monitors different activities of the elderly and determine the wellness of the person. It is a challenge to recognize different activities of the elderly over 24 hours for the seven days a week. The coverage issues in terms of monitoring the elderly are discussed in the paper.

Keywords: Wireless Sensor network, Smart Home, Elderly people.

I. Introduction

With the ever growing advancement in the technological area, the last few decades have faced an upheaval in the wireless communication, advancement in sensing technology, embedded systems, control systems, signal processing. One of the essential uses of wireless communication is to act as carrier of sensing data in smart homes and intelligent buildings. Smart homes are built to monitor many purposes, one of them being for the people who need supervision in their daily lives. Extensive studies have been going on smart home for the last two decades [1][2][3]. Here, in our work, we have dealt with the elderly people. The persons living in those homes will be monitored every moment for their daily activities [4]. In other cases, some cameras or vision sensors are used. But the old people generally tend to live a private life and strictly avoid any use of visual images. For this reason, the sensors that are used avoid any kind of images or videos are not used. A separate house can also be built using different kinds of sensors for the old people to stay. In that way, it would be very useful to collect the real time data of the daily activities. But the old people tend to stay in houses they had been living in for many years due to emotional attachments. It is necessary to connect the wireless sensors with the existing houses. The sensors are fitted only to the objects that are being used in a regular basis to know the frequency of use to detect any abnormal situation. The monitoring of the activities of people staying inside the smart homes are done by keeping a continuous record of the usage of appliances [5] [6] as well as the physiological parameters [7] are checked. Internet of things [8] is the phenomenon used to collect the real time data in the smart home. Change in activity pattern due to seasonal change is also studied [9]. If too much of appliances are used in a day, the amount of data reaching to the monitoring system would be too high and this lead to traffic congestion [10]. Every individual regarding their ability to perform are studied by carry out specific tasks [11]. In the normal case if any device is not used on a particular day or is used for more than the normal time length, then an alarm is send to the care taker to check the condition at that moment. But in the regular activities, the detected sensors send the information to the processing unit. This unit stores the data received at that moment in the database and allows the caretaker to know if any problem has occurred or not. The sensing network can be applied to more than one smart home. In that sense, the connection needs to have a topology so that the information from all the homes can be accumulated in a single unit.

The paper is organized as follows. Section II gives view of the activities of the elderly people living in the monitored smart home. Section III explains each individual task carried out. Section IV shows the

activity timeline of the time the tasks are carried out with the sensors used to monitor them. Section V explains the functioning of the system with section VI giving the other work carried out on this field. Finally, section VII gives the coverage issues with resolutions and conclusions in section VIII.

II. Block Diagram: Representation of Monitored Activities

This section represents the activies an elderly person does everyday for his/her living. The objective of the current Home Monitoring System (HMS) is to know those activites with the help of different sensors. Figure 1 shows three different portions that are interrelated to each other. The activites done, with the devices that are used to do the respective activites along with the sensors used to detect the activities .

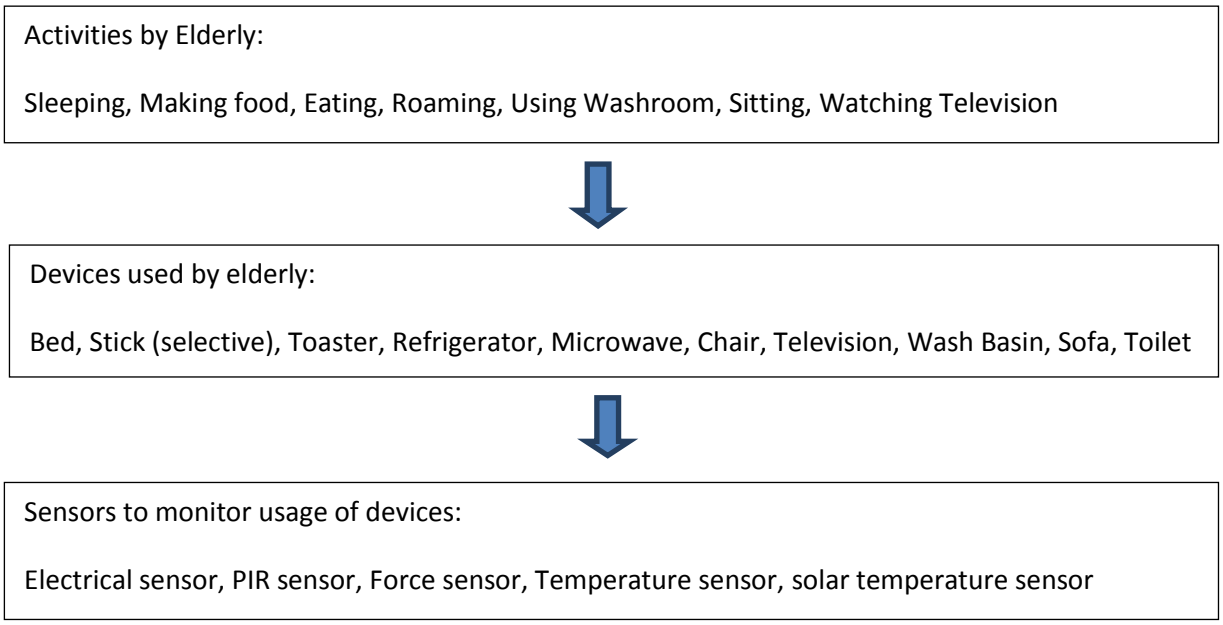


Fig. 1- Activities performed with the types of Sensors to monitor them

III. Determination of Regular Behaviour:

The wellness of the elderly depends on the regular usages of different appliances every day. This section describes the usage of individual appliances for the respective purposes:

1. Usage of bed: Elderly people use bed for sleeping. The bed is monitored using force sensor to know the sleeping pattern and behaviour of elderly person.
2. Using toilet: Toilet is used for excretion of undigested products from a person's body and is used by a person multiple times a day. Toilet is also monitored by force sensor.
3. Preparing Breakfast: This event occurs near about in the scheduled time. During this process, microwave, toaster and fridge are used whose activation is monitored by the electrical sensor.
4. Eating breakfast sitting on the chair: Here, the force sensor is connected to the chair to know the duration for which the person is taking his breakfast.
5. Using washroom: This is temporary usage of wash basin to wash hands. The usage is

monitored by water sensor connected to the pipe to check the inflow of water.

6. Watching television sitting on the sofa: Here, two types of sensors are used simultaneously. The force sensor is used beneath the sofa to know whether the person is sitting or not and electrical sensor is used to know the time duration for which the television is used.
7. Roaming around the room: During this activity, it is hard to monitor what the person is exactly doing. This is because if the person is roaming within the range of PIR sensors, then the sensors will be able to track them. But if the person is standing or has fallen down then it is difficult for any used sensor to detect it.
8. Preparing lunch: This process is similar to preparing breakfast but takes a little long time. The used devices are same, so as the sensors.
9. Eating lunch sitting on the sofa: The person takes his/her lunch on the sofa while the sofa is monitored by the force sensor to know the duration sitting on the sofa.
10. Taking rest for a while: This step is very crucial to an elderly person. An elderly person keeps at least 12-13 hours sleep to have a good health. The person takes rest on the bed which is attached by the force sensor.
11. Eating evening snacks: This is small snack duration for the elderly person.
12. Sitting on a chair taking to any visitor or people staying in the room: In the elder care homes, relatives or other acquaintances visit the elderly people. So, the elderly person meets the visitors sitting on the chair which is fitted with the force sensor to keep a note of the time duration of sitting on that place.
13. Preparing dinner: The person prepares his/her last meal for the day using fridge, microwave and oven. Electrical sensors are connected to the mentioned devices.
14. Eating dinner sitting on the sofa: The person takes his/her meal sitting on the sofa which is connected by the force sensor.
15. Going back to sleep: Finally, he/she goes back to sleep on the bed which is again connected by the force sensor.

The given pictures below depict our system and the constituent devices working on it. Fig. 2 shows the house we used as a smart home. It is an old house where the elderly people stay for more than 60 years. The monitoring system has been operating on this house for over a year. Fig. 3 gives the pictorial view of the laptop used to monitoring all the activities of the smart home. The coordinator is attached with the laptop which receives all the data send by the operating sensing devices. The coordinator is connected via a serial port. Fig. 4 shows the temperature sensors used to monitor the temperature of the room and the ambiance. Fig. 5 gives the pictures of the electrical sensors used to monitor the usage of electrical devices during the day. The sensor passes the information when the device was used with the amount of voltage and current drawn. Fig 5 shows the PIR sensors used to monitor the movement across the room.

Fig.2 House which is used as a smart home for monitoring of elderly activities

Fig.3 Laptop along with the coordinator

Fig. 5 Sensor used to monitor the usage of electrical devices

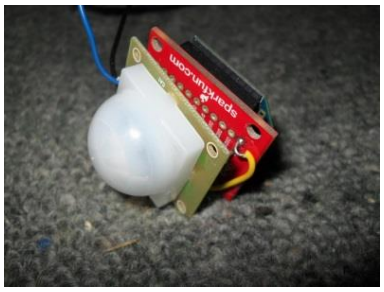
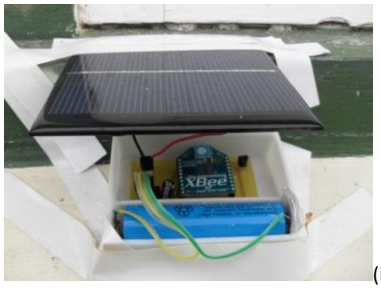


Fig 6. PIR sensors monitors the movement across the room


(i)


(ii)

Fig. 4 Temperature sensors used to monitor the

temperature of the room (i), the ambiance (ii)

IV. Typical activity timeline of an elderly

The timeline of an elderly person is shown in Fig. 7. There might be some discrepancies in the events, but in a usual day, the given day-to-day activities in the timeline are followed. Mainly three types of sensors that are force sensors, electrical sensors and water sensors are used for the detection of elderly activities. Caretakers are allotted to keep a timely note for following the routine. For an elderly person, sleeping is the longest duration in a day. This duration may vary from day to day, but on an average, an elderly person sleeps eleven to twelve hours a day. In a general day, the person wakes up, followed by preparing and eating breakfast. Then the person watches the television for a while. It is followed by preparing of lunch, eating the same and finally taking some time out for himself/ herself before taking rest. The use of washbasin or toilet is done for a few internal within a day. The use of sofa or chair is done only during specific intervals of time, mainly during eating food or sitting on it to talk to other people. But there is a time just after eating lunch and the use of wash basin, no sensors are allotted to detect the activity of the elderly person. After getting up, he/she takes some snacks and talks to other people or any visitor. At last, he/she watches television, prepares dinner, eats the same goes to bed.

Time	Typical activity	Sensors used to monitor the activities
08:00 AM - 08:15 AM	Getting up from bed	Force Sensor
08:16 AM - 08:45 AM	Using toilet	Force Sensor
09:00 AM -09:25 AM	Preparing breakfast (Using Microwave, Refrigerator)	Electrical Sensor
9:30 AM - 10:00 AM	Eating breakfast (Sitting on the chair)	Force sensor
10:05 AM - 11:30 AM	Watching television (Sitting on the sofa)	Force sensor
11:35 AM - 12:10 PM	Preparing lunch (Using Microwave, Refrigerator, Oven)	Electrical Sensor
12:15 PM - 12:55 PM	Eating lunch (Sitting on the sofa)	Force sensor
01:00 PM- 01:10 PM	Using washbasin	Water sensor
01:15 PM - 01:45 PM	Roaming/standing in the room	Not detectable
01:50 PM- 03:30 PM	Sleeping(on the Bed)	Force sensor
03:35 PM- 03:45 PM	Eating snacks (Sitting on the chair)	Force sensor
03:55 PM- 05:15 PM	Talk to any visitor or other people in the room (Sitting on the chair)	Force sensor
05:20 PM- 06:30 PM	Watching television (Sitting on the sofa)	Force sensor
06:30 PM- 07:00 PM	Preparing dinner (Using Microwave, Refrigerator, Oven)	Electrical Sensor
07:05 PM - 07:45 PM	Eating Dinner (Sitting on the sofa)	Force sensor
07:50 PM- 08:00 PM	Using washbasin	Water sensor
08:05 PM- 08:25 PM	Sitting on the chair	Force sensor
08:30 PM-08:00 AM	Sleeping on bed	Force sensor

Fig 7- Activity timeline

V. System description

The main motive of this system is to note that the people living in the house are healthy by collecting the real time data of the activities that is done on a regular basis. Sensors are connected with different devices to monitor their usage on a daily basis. The microwave, fridge, television are connected with electrical sensors. These sensors shows when the attached devices are active. The electrical sensors show when the last time the device was used. Motion sensors are connected across the room to detect the moment of the elderly person. Temperature sensors are used to detect the

temperature of the room. Force sensor is used to know whether the person is sitting on the chair, sofa or bed. Data is continuously stored during the movement of any person. Every sensor that is used in this system has a unique device ID. The system works in two different phases. One is the hardware phase, other being the software phase. The sensing devices are connected in the form of Mesh topology. This type of network topology helps to reduce the power consumption for data transfer. The sensing devices or end devices communicates with the router which as a results sends the data to the coordinator connected to the central monitoring system. The sensing devices and the coordinator communicate with the help of RF communication module called Zigbee modules attached to them. In the hardware phase, these Zigbee modules are first configured. Their configuration is done using the software called X-CTU. The Zigbee that will be connected to the main system is said to be the coordinator. During the configuration, the end devices are given the address of the coordinator of which the data is to be sent. The configured Zigbee modules are then connected to the sensing system called the signal conditioning circuit. Now, each circuit collects the real time data of the device with which it is attached. This value is an analogue value which is converted into digital by the microcontroller using ADC present in the module. The Zigbee with which the circuit is working has a range of 100 meters that is the sensing system can interact with the main data storage device up to a range of 100 meters. Above that, there is loss of data. But if every electrical device is connected with one signal conditioning circuit, then there would be a lot of sensors operating together which would increase the system's complexity with the power consumption. So in order to reduce total power required to operate the wireless sensing network, the sensing system is fabricated in such a way that one sensing device can sense the activeness of more than one electrical appliance that are used in day to day basis. Different kinds of sensors like electrical sensors, PIR (passive infrared) sensors, force sensors and temperature sensors are used to collect data from objects like microwave, fridge, television, moments across the room, present position of the person and the temperature of the respective rooms respectively. These data after being converted and reaching the coordinator is stored in the database. The whole data is at first collected in the main table. This table then divides individual data type to their corresponding tables. These tables then input the data in another table which keeps the data only for one day except for the movement detection where the data cleared after every two weeks. The next day, the last table clears the previous data and takes up the data for that particular day. Continuous flow of data requires a large space to accumulate them in the main storage table. Backup of data from the main data base is taken at fixed intervals to maintain a continuous space available for data to be stored from the coordinator. Microsoft Visual Studio (MVS) for C# is used to write a program for the operation of the respective sensing devices to send the data to the coordinator and store it in the database. The program written in C# is used to design a graphical user interface for the easy operability. The MVS is a windows based application. PHP is used to display the stored data in the web. MySQL is used to create the tables on which would be shown on the web. The table consists of four tables, Senor_ID, Datetime, Channel_No and Value. A particular domain name is registered for the data to be displayed on the webpage. An application called No-IP is used to have an IP address for the webpage.

Other's work

Recent work has been done on smart homes based on different ideologies. In a paper on smarter homes [12], they did a survey regarding the co-relation between human comfort and energy efficiency. A study made on the north house had a conclusion that the settings made in that house could not be altered for human comforts without disturbing the optimal mode of the house. The main objective of the study was in the idea of having a smart home where the light and the thermostat would be customized so that that it operates in a way keeping a balance in comfort level and energy efficiency. The night lights would be work in a four step method where each step would cause in the change in intensity of lights. The first step will cause the lights to glow but in a way that it won't disturb the people sleeping. Second one is to overwrite the first step. The third step involves the maximum glowing of lights when the people in the house are not sleeping, with the fourth one being the lights switched off.

Similarly, the thermostat would cause heating just prior to the coming of the person staying in the home. The device goes into a power saving mode in the absence of any person and comes into a normal state in the presence. This phenomenon works in a two way. In the first step, the thermostat checks if the person is at home. If he does, then the thermostat is turned on get a specified temperature. Also, if the person is outside and has a high chance of coming back home, then also the thermostat is turned on. If the person is not at home, then the thermostat goes off and keeps a power saving mode. Recent work has also done regarding cognitive health [11] as well. It has experimented on a group of people including healthy as well as ones suffering from dementia and mild cognitive impairment. In the basic setup, they had to perform a series of activities which consists of tasks and subtasks. The performance of these activities would be monitored by a number of different kinds of sensors like motion sensors, accelerometers and other types. The final goal of this set up is to determine the sections of people who are healthy as well as people are not. To have a proper ambience, a test bed has been created which consists of two floors having an office, kitchen, bedrooms and a living room. The people entering the test bed undergo check-up from experienced clinicians before doing the task. The task pattern is consisted a "Day Out task (DOT)" where the participants had to complete a series of tasks. Scores were given based on the performance. The live performance of these experiments was seen live through video cameras fitted inside test bed rooms to keep a note on how the tasks are done with the amount of time needed to do them. For the evaluation part, trained clinicians were called to analyse the job done by the participants. The term parallelism was introduced which is defined as the ability to do multitasks sequentially. An index had been defined to grade every individual based on the multitasking performance. It had been observed that the ones with good cognitive health were able to perform well, with the cognitive unhealthy ones were facing problems, while maximum number of dementia patients could not complete the task. The final part shows the amount of people who could complete the task given the proportion of healthy and unhealthy ones. Having a same point of view but on a slight different approach, Federico *et al.* [13] described the working of smart homes for the assistance of the residents. Here, the end devices are placed across the room connected with different operated objects which collects signals and sends it to the end devices. The end devices subsequently send the data to the main station. The connection is made in the form of a mesh topology. Zigbees connected with the end devices are cheap, easy to handle, has a low consumption power and operates at a frequency of 2.4 GHz. The coordinator in the main station interconnected to a gateway collects the data and forwards it for processing. A categorization has been made as cooperative and non-cooperative user. Among the cooperative users, the user interacts with the devices through which the set up can identify the location and activity of the user. But in the non-cooperative one, the user is not using any devices by which the coordinator placed in the main station can recognise the activity. It is only the movements which indicate a signal in this case. Another approach is the learning by example (LBE) where the real time position of a resident is sent to the control station which makes estimation of the probabilistic presence of that user. An app has been installed in the smart phones of the residents to know their relative positions. The station gets to know the position when the app sends the data to it through the nearby routers. Active localization method is formulated to have an estimation of the position. The security problems related to smart homes [10] are also dealt with the approach of different malicious intrusions occurring and quality of service related to it. The system is described as a Smart Home Service network where HAM units are installed in each operating house which is interconnected through Ethernet. The installed units are centralized. This paper mainly deals with security problems and the quality of service related to it. The security problems like theft of passwords, spoofing without authentication, hacking can be dealt with methods like encryption techniques and authentication process. In encryption technique, a cipher is used to transfer the message from the sender to receiver. Here, DHKE method is used for the key exchange. Out of different ciphers like AES-128, RC4, here AES-128 is used, where 128 is the bit length of the key. In the DHKE method, it is compulsory to know both the public and private parameters. But since this method

faces problems like the man-in-the-middle attack, the station-to-station protocol is used. Here, an asymmetric key pair is used between the sender and receiver to maintain the originator of the encrypted message as the claimed one. But the computational cost and maintaining the integrity of message of this advance method is a problem. So cryptographic hash algorithms are used in which the message is defined by the hash. Then with the authentication process, a particular user is allowed only if he given the right to use. Many different entities are used for authentication. A method called 'challenge response' is used where the interaction happens between two parties with one challenging and the other one accepting it. For the security purpose, the user is the first party which sends a request. This request includes the identification of the particular user with some random numbers and timestamps. If accepted by the user, a nickname and a password are given to that user for future references. The quality of service deals with the traffic caused by different applications in the smart homes. Here, since a HAM unit is installed in each operating house, it uses a particular function called "pcap" or packet capture. Here, the process is subdivided into filtering and queuing. In the first part, the filter distinguishes the packets accordingly and forms a queue. The HAM units installed at each house contains a middleware which reports the status of the network to the central server as a result of which it gives controls to reduce the traffic. A strategy called adaptation strategy is used where if data through more than one link is sent with different frequencies, modification of the frequencies are done according to the priority. The work based on cognitive sensor network [2] is described to give a view on the work done on elder care. The sensors are connected to the electrical appliances, bed and the usage of these things is being monitored by the central station based on the signal received from the sensors. The monitoring unit is fabricated in way that a single sensor can be used to monitor the usage of electrical appliances. For communication, the sensing units connected to the appliances, bed or to check the water flow and controller unit have RF transceivers. The electrical appliances connected to the sensing units may have different power rating, thus the current input to the appliance is also different. So, a transformer which is also connected to the AC mains is used to detect the flow of the current and produces an output voltage. This voltage is then amplified and passed through a comparator given a reference voltage. The output of the comparator is then passed to the certain pins of the microcontroller and is worked upon. The water sensor is also used calculate the follow of water to know the usage of it at particular intervals. The flow sensor detects the flow of water and informs to the monitoring unit through the microcontroller. The bed is monitored using force sensor which is placed under the legs of the bed. The signal generated can be used to monitor the quality of sleep a person is having. If the signal from the sensors is constant, then the person is having good sleep and vice-versa. A panic button is present with the elderly to call in case of emergency situations. The wellness determination [9] is one of the important parameters used to calculate the wellbeing of an elderly person doing his/her daily activities. This parameter is determined by forecasting and by the use of time series. This forecasting of future events is made based on the fact that there would be change in the cycle of events depending on the seasonal change. The activities done by the elderly person is continuously recorded in the data base. The data is continuously collected for nine weeks and is based on the fact that one week is considered as one season. The pattern or trend based on a season is calculated by the principle of moving average. Some of the electrical appliances are auto programmed, so the intervals for which they had been used previously will not be taken into account. Since for varying activities done by human beings from day to day, the data within one season also varies. So another method called Seasonal Auto Integration with Moving Average (S-ARIMA) is used. Seasonally adjusted factor is considered and accordingly most of the data collected is accurate with a slight variation. Sensing devices are also used to measure the physiological parameters [7] like heartbeat, temperature. The basic idea for the function of the system remains the same, that is, the sensing device consist the Zigbee module which sends the measured data the computer and is displayed using a graphical user interface. The temperature value measured is in analogue value which is converted by the microcontroller using ADC. The temperature value is taken from the skin. The

measured analogue by the sensing device is converted to digital and then a formula is used to get the original value. The temperature is measured both for males and females. The heart beat for a person is measure in three different regions of the body. NIR technique is used to measure the heat beat. In this technique, light is emitted of a particular wavelength for which the tissues will not absorb but the haemoglobin will. The accelerometer is used as an impact sensor to measure to impact in the body of a human being. During a stroke, there is sudden impact else normal wellbeing gives an out of square wave pulse in the oscilloscope.

VI. Coverage Issues and limitations

Even though the overview of the sensing network works fine in general for a day to day basis, but there are some limitations that we have come across. Though many sensors are already in use to determine different activities of the elderly, it still might have a situation when it is not possible to know the state of the person. These limitations have to be dealt with to make a nearly perfect ambience for an elderly person to life in. This can be controlled if a continuous monitoring is done on every aspect of a person, the emotional state being one of them. In the activity timeline shown in Fig 2, there is a span time of time when no sensor could be used to monitor the activity of the elderly person. The span shown in the fig is for a given time, but this time may vary from day to day. Also, it is very important to know how the person is feeling, especially when the dealing is done with an old person. If the person is sad or tensed, then it may lead to heart problems. Moreover, when the person is sitting idle in a chair or sofa, we don't know that is the state of him/her. If that person gets a stroke in a space where he/she is sitting alone or in a toilet, it would be very difficult for other people to inform immediately the central monitoring station to take urgent actions due to the similarity of age with the people around. Another problem is the occurrence of glitch that is sudden changes in the daily routine. In those cases, a false alarm would be buzzed. On a long term, it may cause problem due to repeated occurrence of this. Shoe monitoring is one of the issues that can be dealt with. The sensor should be placed inside the shoe so that accidental falling of any liquid on the shoe will not damage the sensor. The sensor present inside the shoe can detect the present position of the person. If the position does not match with the data in the activity timeline, the abnormality would be reported. The presence of shoe sensors is advantageous because even though the PIR sensors present in a room can detect the presence of a person, but it cannot specifically locate any particular person. So with the presence of shoe sensors on every person present in the home, the data collected at the coordinator can keep a track of them. The collected data in the database would have values from different sensor IDs. This would be helpful to locate the position of the person in case of an emergency. Wearable sensors can also be used to detect any kind of fall. The sensors should be attached externally so that if the person changes clothes from day to day, the sensor can be taken off and attached to the worn one. Wearable sensors have the advantage that if the person faces a sudden fall, the monitoring system can locate the exact location of the sensor and that required actions. In the case when the person does not move from a particular position besides being on the sofa, chair or bed, the situation can be monitored and data for the particular movement can be stored in the database.

VII. Resolution and Conclusion

A buzzer is one of the solutions that could be used hung around the neck as a chain as so that when he/she is facing a heart attack or related issues, the person can immediately press the buzzer to raise an alarm to inform the monitoring unit. Now the question arises how to make sure if the buzzer is working 24/7. In that case, one alarm can be fitted in the room to make sure that if an alarm stops working, then the person wearing it can press the room alarm and accordingly the caretaker can replace the faulty one with a working one. To know, about the negative emotional state of a person, we have to know the heart beat and oxygen levels of that person. It is generally seen, that when a person is sad or specially tensed, the heart beat increases. So, to keep a note on that, devices can be used to know the heart beat and oxygen levels. The problem of glitch is common in any situation. It may occur

that the person living in a home gets bored of the regular routine and tries to do something different on a particular day. In that case, initially an alarm will raise for the breakage of regular routine but that data can be stored in that database for future preferences. If that person brings a breakage of daily routine again in the future out of boredom, that data can be compared to avoid the alarm. Shoe monitoring is another solution that can be considered to keep a track of the movement of individual persons in the house. If the above steps are followed in a disciplined manner, it may bring a sensible smart home for the elderly people.

VIII. References

1. Muhammad Raisul Alam, Mamun Bin Ibne Reaz and Mohd Alauddin Mohd Ali, "A Review of Smart Homes—Past, Present, and Future", IEEE Transactions on Systems, Man and Cybernetics- Part C: Applications and Reviews, Vol. 42, No. 6, pp. 1190-1203, Novermber 2012.
2. A. Gaddam, S. C. Mukhopadhyay, G. Sen Gupta, "Wireless Sensors networks Based Monitoring: Review, Challenges and Implementation Issues", Proceedings of the 3rd International Conference on Sensing Technology, November 30 to December 3, 2008, by S.C.Mukhopadhyay, G. Sen Gupta and Ray Y.M.Huang, ISBN 978-1-4244-2177-0, IEEE Catalog Number CFP0818E-CDR, Library of Congress 200891166, pp. 533-538.
3. S. C. Mukhopadhyay, Anuroop Gaddam and G. Sen Gupta, "Wireless Sensors for Home Monitoring - A Review, Recent Patents on Electrical Engineering", Vol. 1, 2008, pp. 32-39.
4. G. Sen Gupta, S.C. Mukhopadhyay, Michael Sutherland and Serge Demidenko, Wireless Sensor Network for Selective Activity Monitoring in a home for the Elderly, Proceedings of 2007 IEEE IMTC conference, Warsaw, Poland, 1-3 May 2007, pp 1-6.
5. Anuroop Gaddam, Subhas Chandra Mukhopadhyay, and Gourab Sen Gupta, "Elder Care Based on Cognitive Sensor Network", IEEE Sensors Journal, Vol. 11, No. 3, March 2011, pp. 574-581.
6. A. Gaddam, S. C. Mukhopadhyay and G. Sen Gupta, "DEVELOPMENT OF A BED SENSOR FOR AN INTEGRATEDDIGITAL HOME MONITORING SYSTEM", IEEE International Workshop on Medical Measurements and Applications, Canada, May 200 A. Gaddam, S.C.Mukhopadhyay and G. Sen Gupta (2008), "Development Of A Bed Sensor For An Integrated Digital Home Monitoring System" Proceedings of IEEE International Workshop on Medical Measurements and Applications, Ottawa, Ontario, Canada, May 9-10, 2008, pp. 33-38.
7. K. Kaur, S. C. Mukhopadhyay, J. Schnepper, M. Haefke and H. Ewald, "A Zigbee Based Wearable Physiological Parameters Monitoring System", IEEE Sensors Journal, Vol. 12, No. 3, March 2012, pp.423-430.
8. Sean Dieter Tebje Kelly, Nagender Kumar Suryadevara, and Subhas Chandra Mukhopadhyay, "Towards the Implementation of IoT for Environmental Condition Monitoring in Homes", IEEE SENSORS JOURNAL, Vol. 13, No. 10, pp. 3846-3853, October 2013.
9. N. K. Suryadevara, **S. C. Mukhopadhyay**, R.Wang, R.K. Rayudu and Y. M. Huang, Reliable Measurement of Wireless Sensor Network Data for Forecasting Wellness of Elderly at Smart Home, Proceedings of IEEE I2MTC 2013 conference, IEEE Catalog number CFP13IMT-CDR, ISBN 978-1-4673-4622-1, May 6-9, 2013, Minneapolis, USA, pp. 16-21.
10. Markus Hager, Sebastian Schellenberg, Jochen Seitz, Sebastian Mann, and GunarSchorcht "Secure and QoS-aware Communications for Smart Home Services", IEEE, pp. 11-17, July 2012.
11. Prafulla N. Dawadi, Diane J. Cook, Fellow, and Maureen Schmitter-Edgecombe "Automated Cognitive Health Assessment Using Smart Home Monitoring of Complex Tasks", IEEE Transactions on Systems, Man and Cybernetics: Systems, Vol. 43, No. 6, November 2013.
12. Stephen Makonin, Lyn Bartram and Fred Popowich "A Smarter Smart Home: Case Studies of Ambient Intelligence", IEEE Pervasive Computing, Vol. 12, No. 1, pp. 58-66, January-March 2013.
13. Federico Viani, Fabrizio Robol, Alessandro Polo, Paolo Rocca, Giacomo Oliveri and Andrea Massa, "Wireless Architectures for Heterogeneous Sensing in Smart Home Applications: Concepts and Real Implementation", Proceedings of the IEEE, Vol. 101, No. 11, pp. 2381-2396, November 2013.