IoT-based Google Duplex Artificial Intelligence Solution for Elderly Care

Divya Ganesh[1], Gayathri Seshadri[2], Sumathi Sokkanarayanan[3], Sharanya Rajan[4], Mithileysh Sathiyanarayanan[5]
Department of Electronics and Communication Engineering
Sri Sairam Engineering College[1,2,3], Chennai, India
Srishti i2i Biz Solutions & TalentBiz[4,5], New Jersey, USA
divsreevi@gmail.com[1], gayathrigayatri817@gmail.com[2] , sumathi.ece@sairam.edu.in[3], mithileysh.s@srishtibiz.com[4]

***Abstract*— The advancements in medical science and technology has resulted in an increased life span thus the mortality rate of the elderly has greatly decreased. The elderly often gets cognitively impaired and require urgent medical services which when left unnoticed may lead to fatal consequences. Due to lack of social care support for these adults, there arises the need to develop cost-effective assistive healthcare technological solutions for taking care of the elders and giving them the best tech-friendly experience. Intelligent homes, an environment of sensors with artificial intelligence integrated with home appliances, can provide the best solution for continuous and remote monitoring of the health of the persons. This helps elders to control various devices, also get immediate attention from the family members, healthcare assistants and/or have frequent visit to hospitals. Basically, an intelligent bed can help elders to prevent the occurrence of bedsores and falling off from bed by monitoring the position of the person while they are in bed. The latest Google Duplex Artificial Intelligence (AI) will be used as a voice-controlled speech recognition system, a personal assistant, to respond to the commands given by the person. We use Internet of Things (IoT) to establish the connectivity between the appliances, the user and his/her network. The major element of this system is a Raspberry Pi which will collect the data from the sensors and interprets them to manage the home appliances like light, fan, door, alarm (in case of emergency), manage phone calls, television, and other home appliances. There is also an emergency module which has sensors attached to the body of the person which helps the caretakers, relatives or friends to know about the health of the person. It continuously monitors the body conditions of the person and alerts his/her network in case of emergency.**

Keywords*— *Internet of Things, elderly, disabled, smart bed, bed sores, fall off from bed, raspberry pi, personal assistant, caretakers

I. INTRODUCTION

Currently, Internet of Things (IoT) is being used as a major tool for research and development around the world. IOT has enabled people to get information about many integrated gadgets in their daily life. In India, the population of people, more than 65 years is projected to increase from 5.8% (as of 2016) to 8.5% in 2030. It is also applicable for the developed countries such as the US, China, Japan etc. For the US the estimated ratio ranges between 15.0% to 20.4%, China ranges between 10.1%-17.1%, Japan ranges between 26.6%-30.3%. IoT consists of several modules based on functional attributes such as Sensing, Actuation, Communication, Analysis & Processing. Automation of rooms requires user-friendly, flexible and well-integrated devices as the application of gerontechnology [1]. The elderly and disabled people who depend on others may require frequent, an immediate medical intervention which if untreated results in harmful effects and it may also lead to irreversible consequences and or death. Rooms with smart beds accompanied by personal voice assistants can be seen as a paradigm shift in medical care for the elderly. This paper presents remote, efficient and non-invasive health care systems with adjustable designs. Simulation of smart beds along with the real-time monitoring of body parameters using Body Sensor Network (BSN) can be achieved by sending the data to the central computing system using sensors which in turn assists caretakers to monitor continuously. This system mainly focuses on helping the elderly and the impaired mobility of people living alone. The smart bed has the inherent feature of preventing persons falling from the bed. In addition, it prevents further complications of chronic diseases such as bedsores, stroke, trauma, dementia etc. The wireless sensors attached to the body of the person continuously monitors the health conditions of the person and alerts the caretakers or the relatives by sending messages through internet during emergency situations such as falling from bed, pressure applied at specific regions for long time, through abnormalities found in the signals obtained through the BSN. Personal assistant converts the information based voice outputs into commands and controls the appliances, household gadgets, e-mails, files and stores important dates. Data privacy is achieved since there is no usage of modern cameras in this system. The system faces the challenge of power outage. This can be overcome by the use of the low power designed sensors. And in the transmission of the data using the Wireless BSN requires the need of the internet with high-speed connectivity and reliable network as it may need to transmit the real-time monitoring signals. The need for the system is shown in the graph which describes the growing population of the elderly in society. So there is an immense need for us to provide an user-friendly environment and take care of the elderly in the best way. Here the figure 1 explains the fast growing elderly population across the world, referred in [2].

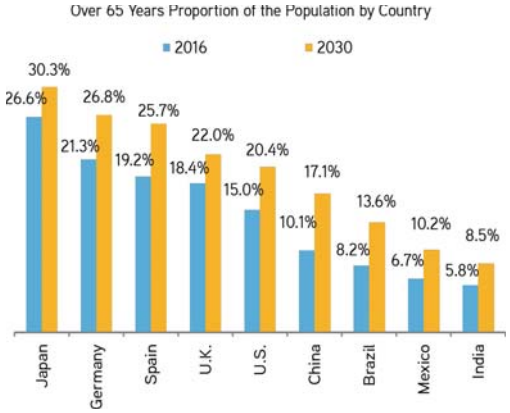

FIG-1 : Population growth of the elderly across the world from [2]

II. Technical Review

This section discusses the review of smart home control. In "Smart Homes for Elderly Healthcare" [3], the authors describe the remote health care technologies using the body sensor. The system collects some of the body parameters such as ECG, HR, Pulse rate, BP, SpO2, GSR, temperature, joint movements with the help of body sensors and the signals are sent to the transmitter and processed to provide remote healthcare services. The system takes advantage of monitoring of the person in real-time and this can help in generating alert signals in emergencies. This system suffers a major challenge of the volume of information needed to be transmitted due to a large number of sensors, battery usage, privacy and data security. For measuring the body parameters [4] the sensors collect the data and using the Bluetooth data is shared to the center computing system. This continuous monitoring can help detect cardiovascular diseases at the early stage. The body sensor network is designed such that they do not disturb the normal physiological activity of the person. These parameters can be measured using the minimum number of sensors using [4]. This is almost similar to the proposed method in which only certain parameters are considered for monitoring. For the Bluetooth, the Ultra-low power (BLE) is preferred for portability and less battery power.

Coming to the bed design, the fall detection using wearable camera [5] monitors the activity of the elders. The wearable camera has the advantage of monitoring the person's movement without restricting them to a specified area. The fall detection is implemented by obtaining the histogram of the edge of the image and during a fall, a vast distortion in the image (blurred) can be observed, which indicates a fall has occurred. It ensures privacy such that the person's image is not captured but only transmits the whereabouts of the person. The beds using the MAP technology [6] used to prevent the occurrence of pressure ulcers using the pressure sensing mat, a special electronic sheet, that has thousands of the sensors placed on the mattress below the person. As a result, it can monitor the pressure at points using imaging technique and give efficient repositioning when pressure is applied at points for a long time thereby helping the caregivers. The sensors count and the cost of implementing them make this ineffective. Another type of bed includes air chambered mattress [7] which can automatically control the pressure at an area by regulating the air inside the cavity beneath the bed sensors using air pumps. The bed is divided into 5 different zones (head, shoulder, lumbar, hips, legs) to customize the firmness of the mattress according to the user. It uses the application to control the firmness of the bed by regulating the air supply to the chamber. It is used for pain treatment. But it is uneconomical. The sensors placed in the beds of FSR type [8] are FSR 406 and FSR 408. This is referenced for the design of the smart bed here. The FSR 408 (Strip type) is used in the head, neck, hip regions whereas FSR 406 (square type) is implemented in the spine and elbow positions. Smart beds [9] discussed the utilized technology to help the physically impaired persons in preventing from accidents and bedsore avoidance. The mattress is made using the FSR sensors placed in specific areas in bed according to the points of the frequent occurrence of the bedsores. This has the advantage of the mobility of the bed. This is similar to the proposed method in this paper regarding monitoring the pressure in the bed but it fails to recognise the position of the pressure ulcers in a person's body in a bent position.

During the sleep, the bed assesses and determines the minimum time required for application of pressure at a specific point to prevent bed sores [10]. The sleep sensing system [11] measures the quality of the sleep of the person at home. It uses thin sensors named Flexiforce sensors for determining the posture, quality of sleep and so on. The sensors are kept at 4 points under the legs of the bed. It can calculate the weight of the person. It is easily deployable, less complex and costly. The transient responses of the four sensors determine the sleep quality of the persons. In personal assistant voice-controlled automation [12] we have Google assistant to capture the voice and process it using the Arduino Uno via Bluetooth for controlling the home appliances such as light and fan. It also has the mobile interface application for controlling the appliances. As the system is taking voice input, it is very sensitive to disturbances like noise, building borne echoes. The voice-controlled home automation [13] uses the IOT and Raspberry pi and work on the python platform to achieve the home automation. The Raspberry pi collects the signals from sensors or speech or gesture commands, processes them and controls the home appliances. It also uses the Google Speech Recognition application interface (API) to pick up the speech taken using microphone. It also has the feature of Google search. Its functionality is limited due to the range for picking up the signal is limited and gesture controls recognized by image processing technique may fail to predict correctly due to the background lighting. But it is easily designed and has fewer complications.

III. System Design & Methodology

The method of achieving this requires two modules, the one for the IOT integrated home automation and the other is the designing of smart bed. The method 1 is described below.

The first module is the integration of the body sensor network and the speech recognition system. As the popularity of smart home technology has increased the special attention of Internet Of Things (IOT) with the help of a personal assistant devised by the researchers [13]. The purpose of developing a personal assistant is to provide the elderly and physically challenged people with environmentally friendly and interactive living experience. The voice recognition system acts as a personal assistant which gets the voice of the person and controls home appliances such as light, fan, television sets, heaters etc[14]. The use of sensor networks for healthcare has growing needs in ubiquitous communications and there has been considerable interest in the development and application of wireless networks around humans. With the maturity of the wireless sensor network such as Body Area Network (BAN) and Wireless Body Area Network (WBAN) are developed. The recent advancements in promoting the concept of Body Sensor Network (BSN) aims to move beyond sensor connectivity and adopt a system-level approach by addressing some of the issues related to biosensor design, interfacing, and embodiment, as well as ultra-low-power processing and communication, power scavenging, autonomic sensing, data mining and integrated wireless sensor microsystems. And this paves the way for this technology to be rrecognized as a widely accepted method of organization for routine monitoring systems.

A. Design of the System

As the development of such technologies increase, special attention is given to build a wide range of sensors. The work aims at building a body sensor which is to be placed on the

body of the person to monitor their health. The elderly and the physically challenged people are facilitated with wireless physiological sensors such as BSN, which will continuously monitor the condition of the people with the help of the PDA [15] and transmits the data to the caretaker. It also alerts them during emergencies. BSN transmits data using WLAN (Wireless Local Area Network) and follows the basic concepts of star topology [16]. The transmission of data is handled by wireless links. This is used to sense the full process without the use of battery which can provide an increased lifetime of the entire process compared to the battery-powered systems. This can be achieved by placing the transmitter very close to the patient's skin and thus the energy consumption is minimized in this system. As per the report, the estimated accuracy is at the rate of 90% from a distance 8.2m. The detailed review about the data transmission system by wearable sensors is explained in [4]. The sensors transfer the data only in the presence of internet. In the body sensor network, the sensors are placed on the body surface which enables information to perform the initial processing. The data is gathered and transmitted to the caretaker by sharing the information over the internet. The sensor module collects the status of the person and converts the data from the physical signal to the electrical signal. The sensors used in this procedure are used to monitor various parameters of the patient such as ECG, HR, BP, GSR, RR, SpO2, and Temperature. All these measurements are made possible by the use of few sensors such as ECG, GSR, PPG and Temperature indicators which are fixed to the body of the person. They are fixed to the body of the person at specific locations as shown in figure 2. The remote control home automation system is used in which voice commands can be used to control a large number of devices such as lights, fans, television sets and heaters. This technique involves converting the physical experience such as speech into information or data through the sensors and smart devices. To enable the voice-controlled automation we can either choose systems like online or offline voice recognition depending upon the chosen voice recognition technology. Most of the manufacturers also provide (Application Program Interface) API'S that can be used to integrate applications or entire devices with online voice recognition. First, the input voice is captured and sent to the Raspberry Pi via the Bluetooth module and the received signal is processed to the control for fan and light. The Bluetooth range has been demonstrated up to 20 meters range for controlling the devices.

The next module is the designing of the smart bed, which helps the caretakers to continuously monitor the elderly and the physically challenged even during their sleep. This smart bed consists of the pressure sensors placed in the outer cover of the bed at specific positions. These positions are selected as they are prone to the occurrence of the bedsores as mentioned in [17]. It also monitors the position of the person while they are in the bed and prevents fall from the bed.

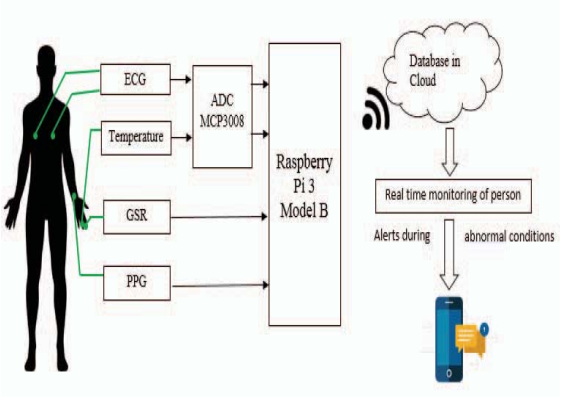

FIG-2 : Integration Of Sensors With Human Body

The sensors placed over the bed cover can get the pressure intensity due to the weight of the person sleeping on the bed, and hence can know which areas of the body that are pressed for a long time and this acts as a trigger to alert the caretaker to change the position of the patient to prevent bed sores. The smart bed is designed according to KATS to find the accurate points where the bedsores are prone to develop. Some of the vulnerable points are ear, scapula, superfine projections, elbow, sacrum, illiac crest, spinous position, toes, knees, etc [17].

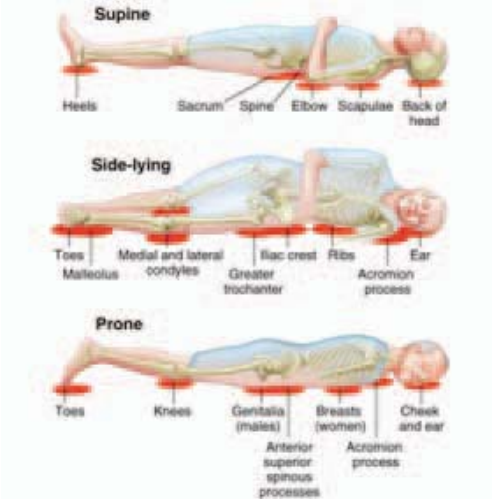

FIG-3 : Positions Of Frequent Occurrence Of The Bed Sores from [19]

A. Design of the Smart Bed

The smart bed has varying sizes that can accommodate the entire body of the person, that is the standard size 183 cm × 216 cm (72 inch × 85 inch) [18] is generally found useful for medical purposes. It is designed for persons of average height of 150 to 180cm. This bed is designed to avoid the bedsores which have an additional feature of fall detection also. As per the study, the bedsores occur depending on the two main factors- intrinsic and outside. The intrinsic factors embody immobilization, psychological feature deficit, chronic unwellness (eg. polygenic disease mellitus), poor nutrition, use of steroids, and ageing. The four outside factors which causes these wounds are—pressure, friction, humidity, and shear force. These will be prevented by continuous

observation of the patient's posture throughout sleep by victimization. To collect the signals from all the sensors which are placed over the bed microcontroller such as Arduino MEGA 2560 can be used. The Raspberry pi takes the control of the central network terminal. This microcontroller will transfer the data to the central network terminal periodically using a Wireless Local Area Network (WLAN). The network terminal will convert the data and store the informatio in the database followed by the cloud for future long-term storage that acts as a permanent database. This data will be interpreted and if the pressure is applied for a long period, a warning message will be sent to the caretakers' mobile via a Google FCM (Firebase Cloud Messaging) server. The main advantage of the system is that the mobilty of the bed is a great asset.

B. Deployment of the Smart Bed

Depending upon the body size of each age group we have to decide the position of sensors on the bed. The importance is given to the position of placing sensors which are close to the problem source. This type of sensor placement will give the data that has a greater impact on the result. Thus the sensors will be placed depending on the positions of frequent occurrence of bedsores and the average body size of the persons (reference given by KATS). In the deployment of the sensors, there are body parts which do not require much intension and we have other parts which are given more intension called as the pressure points. These points are identified as shown in the figure 3 which is inferred from [19]. Here we have the head region and the lower region areas where it is only enough to measure the development of pressure. But in the upper part, we have the more specific areas of occurrence of the bedsores compared to the other parts of the body, so it is essential to measure the pressure closely around that specific region. For implementing this, the use of FSR-406 & FSR-408 can be accurate. The FSR sensor model is a Force Sensing Resistor in single-zone optimized for use in human touch control of electronic devices. In describing the sensors, the FSR-406 is a square type sensor of dimension 38mm X 38mm [20] which is used to measure the accurate pressure at the points. The FSR-408 is a strip type sensors of dimensions [21] which can be used to find whether the pressure is applied or not.

These two sensors can sense the applied force and as the applied force increases the voltage value at the output also increases. The FSR-406 can find the accurate areas of the force applied and are placed in bed in a pattern at specific points. But FSR-408 can find the strength of the pressure alone. It can be placed as a grid pattern in the lower body regions and head regions of the bed. The grid pattern sensor points can be taken as a point in coordinate points as (x_o,y_o) where the pressure is applied. As per the FSR-406, the exact position of the pressure applied can be monitored. They are placed exactly in the shoulder region of the body covering the upper part of the body. It is also placed in the elbow positions. The implementation has 18 FSR-408 sensors and 27 FSR-406 sensors covering a total of 45 sensors. These sensors are taken for measurement considering their ease of use and the cost. These sensors are placed at the specific 10 supine and 12 lateral positions of the body. As per the study, it is shown that to prevent the bedsores from occurring the person's position needs to be changed for every 2 hours [10].

IV. Experiments

A. Method 1

In the experiment section of the IOT personal assistant, the system could respond to the command signals of the person and control the home appliances. The block diagram is in figure 4. The voice of the person is taken by the Google assistant and the Raspberry pi will act as the computing system to process the voice commands. The Raspberry pi is connected to the control module as shown. The control module (such as relay) can be used to control the connected appliances to the system.

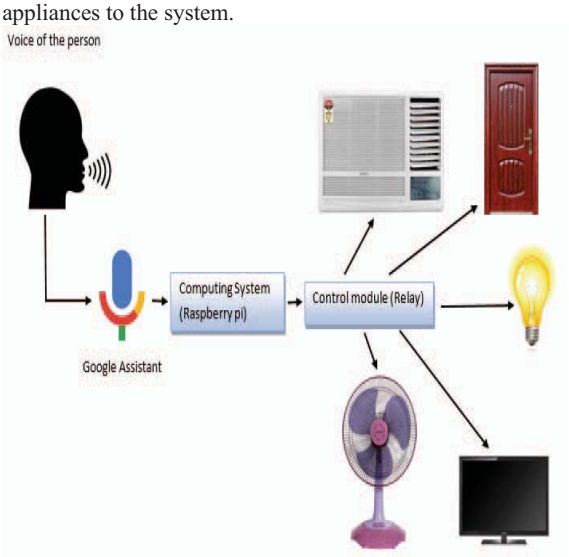

FIG-4 : Block diagram for voice controlled home automation

B. Method 2

In the Smart Bed module, the bed will determine the position of the person during the sleep and prevent them from falling off the bed and avoid the occurrence of bedsores. In the experimental part, the person is made to sleep on the bed and the readings are taken to find the accuracy of the results. To achieve this detection, the sensing algorithm is designed as shown in figure 5. This sensing algorithm makes use of the timer which is set when the person is on the bed. This activates the sensors and the timer is set to the minimum value of the 30 minutes [9]. If the person on the bed is in the same position for more than 30 minutes then the alarm or warning message is sent to the caretaker. The timer is then increased and set to have a snooze time of 5 to 10 minutes. Even after the snooze interval if the position of the person is not changed, the alarm message to the caretakers mobile will be sent continuously for every 5 minutes until the position of the person is changed. Once the position is changed to a new position then the timer is reset to again a period of 30 minutes. In addition to the bedsore avoidance, the fall detection system also works hand in hand, which continuously monitors the pressure in the load cells which are placed on the side of the bed. Load cells will be placed to the left and right side of the bed and the position of the person on the bed will be monitored. Once the person is at the corner of the bed, i.e, the possibility of fall is very high then the alarm with the warning message is sent to the caretaker through the mobile.

The warning can be the message alert given describing the position of the person in the bed. The bed is separated into levels as the minimum level which has no or less falling probability, moderate level with the probability in range of 0.4 to 0.6 for the falling, maximum level which assures a certain fall from the bed. At the maximum and moderate levels the caretakers are given the information to avoid fatal consequences. The design guarentees the mobility of the bed. The position of the person in the bed can vary and some of the positions are shown in figure 6 source from [27].

TABLE I. DISTANCE OF BLUETOOTH ABILITY TO SEND AND RECEIVE DATA

Distance (m)	Send and receive data
5	Success
10	Success
15	Success
20	Success
25	Failed

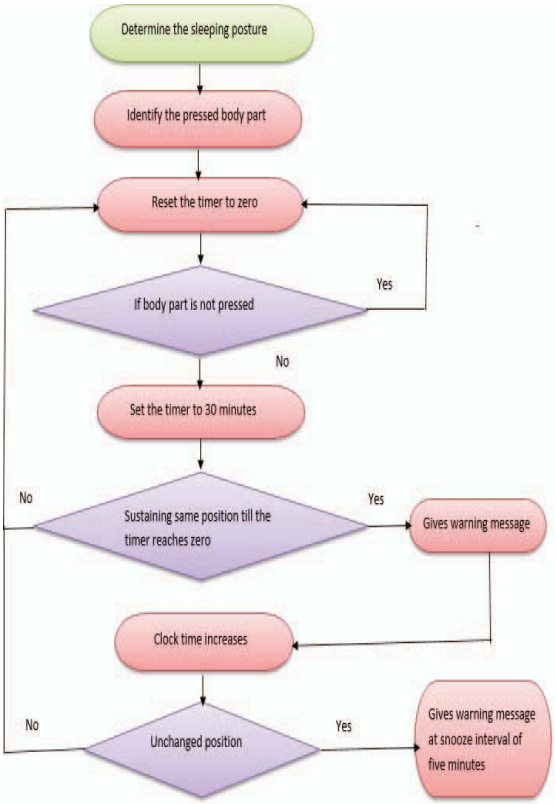

FIG-5 : Sensing Algorithm for the Bed sores prevention

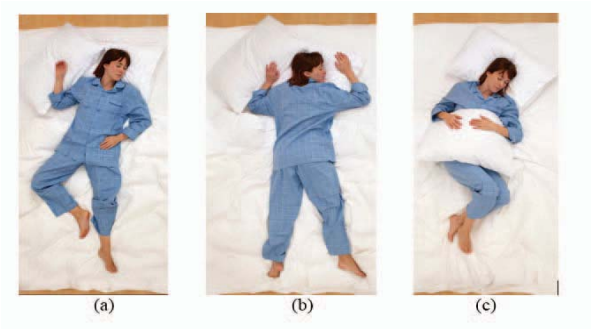

FIG-6 : Different posture of a person while sleeping in the smart bed from [27]

V. RESULTS

This section includes the graph obtained by showing various body parameters such as ECG signal of the person, Heart rate, PPG, Heartbeat, and Body Temperature as shown in Figure 7. The need for their measurements is given in [3]. ECG sensors are also known as the wet sensors. ECG sensors create a conductivity between the skin and the electrodes and then continuously monitors the rate of the cardiac cycle and blood pressure in the outer and small vessels of the skin. Photoplethysmogram (PPG) sensors emit light signals such as infrared (IR) into the skin and the continuous reflection of the signal is used to measure the weak blood flow area in the body. Galvanic Skin Response (GSR) signal [22] works by detecting the changes in the electrical activity of the body such as changes in sweat gland activity. The electrodes placed on the skin must be sensitive to these occurring changes and able to transmit the information to the recording device.

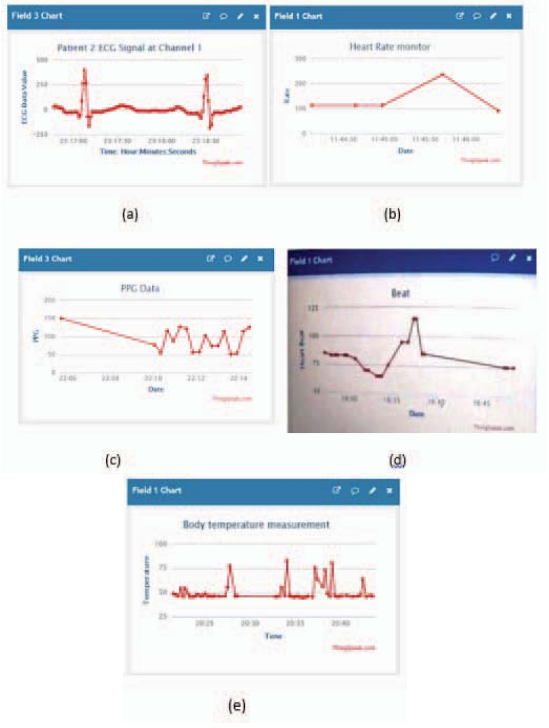

FIG-7 : Outputs of body sensors network

These graphs are obtained by connecting the sensor to the body of the person and updating the values in the cloud. The values from the cloud are used to plot the graph and detect the abnormal variation in the person to help caretakers by giving an alert. The results of the voice-controlled Google assistant consist of the Raspberry pi connected to the light bulb using the relay. The voltage regulator is used to control the voltage supply. The figure 8a shows a light can be tuned off when "BULB OFF" is given as command to the Google assistant and the figure 8b shows when a light can be turned on by giving the command "BULB ON". The screenshot of the command given to the system is given in figure 9.

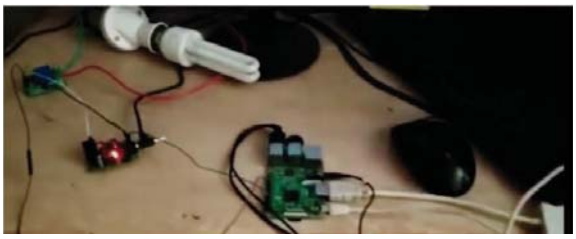

FIG-8a : Light when turned off by Google assistant voice command

FIG- 8b : Light when turned off by Google assistant voice command

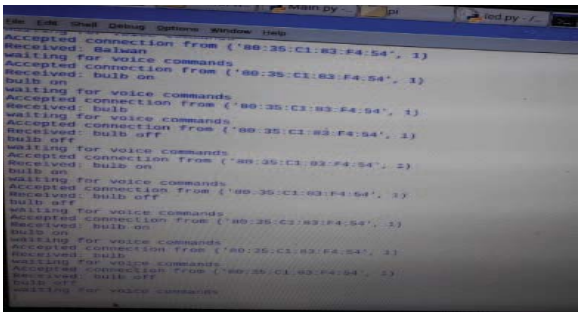

FIG-9 : Screenshot of the commands given to raspberry pi using Google assistant

VI. Conclusion & Future Works

The current work is based on taking care of the elderly or disabled people and providing them a user-friendly living experience. This paper describes the operation of the body sensors which are placed on the patient's body for continuous monitoring of the health of the person. These wireless sensors present in this system sends the information to the transmitter in the BSN using the internet. These sensor signals are processed and stored in a local database. The smart beds are capable of sensing information with the help of the FSR sensor placed in the bed, and gives information about posture of the person lying in the bed, this information acts as the best solution for preventing the person from accidentally falling off from the bed. If any abnormalities arise such as falling from the bed or a prolonged pressure applied in the specific ulcer areas or any abnormal bio-signals from BSN, the system will generate a warning message to the caretakers' mobile phone. The voice recognition system has estimated the Bluetooth range up to 20 meters and can be used for controlling many applications. This system is built specifically for enabling the elderly people or the physically challenged to have a comfortable lifestyle. The overall aim of this system is to provide one of the possible solutions for preventing bed sores and falling accidents by continuously monitoring the elderly or the physically challenged person thereby providing user-friendly living experience. But the system is purely dependent on internet for the sending signals from the body for continuous monitoring.

Though we have the advancement in the smart room technology there are ample chances for the further development and improvement of the system. In this paper, the future works may include the monitoring of the sleeping parameters such as depth of the sleep and duration of the sleep which helps to track the stress and BP levels of the person. Monitoring the breath of the person can also be included along with the HR system. For elders, the nervous system may get weaker, they may have weaker sense of excretion, so urination and incontinence [28] can be monitored. This also helps the mobility impaired persons. This sensing module can be very helpful for nurses and caretakers in the hospitals for monitoring the urine in the bed or in the diapers. In addition to the fall prevention circuit, assuming the fall has taken place, the design of the smart floor with sensors can detect the person lying on the floor. During sensing, if three or more tiles come to the ON state, we can interpret that the fall has taken place. This can send the emergency message to the caretaker to help the person to get up if the tiles are in 'ON' state for more than the timer limit say (e.g. 1 minute or more). This can be an added advantage for preventing the fall of the patient compared to the proposed method. The personal assistant used can be further improved to control the room settings. The automatic background change of the room can help to improve the mental health of the mobility impaired person to a greater extent. The use of the actuators to open and close windows automatically by sensing the day and night, the automatic playing of the music according to the schedule, controlling the doors to ensure the security can be added features that can be implemented in the future.

This paper relates to implementation of the system at home. This can be implemented in hospitals and nursing homes for the safety and comfort of patients.

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