HOPE: An electronic gadget for Home-bound Patients and Elders

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Abstract— **Home-bound patients, mostly elders face many problems regarding their critical health parameter variations and timely assistance in case of emergencies. It is really a malady when they suffer from other severe diseases, heart problems etc. A constant and reliable assistive technology is essential while taking care of home-bound patients. The system, HOPE we have proposed has sensors to monitor the heart rate, body temperature, tilt and fall. The sensors are attached to the body of the elderly patient in a contented manner. The data can be sent to any Smartphone with Bluetooth support. In case of any emergency the caretaker will be given a notification about the critical situation. The provision to monitor the posture of the patient in the bed helps to reduce the cases of bedsore in bedridden elders. Day by day the menace of weakening health and chances of skin related problems, bed sores etc. are becoming critical in case of bed ridden patients. The experimental results presented in this paper give some insight into the behavior of the proposed system**.

Keywords- physiological parameters, photoplethysmography, bed-ridden, care-team,

I. Introduction

Providing quality and timely heath care for the elderly has always been area of concern for the younger generation. Employment, Work stress and other family issues has always convoluted this problem. Though old age homes and elder care centers has emerged as a possible solution to this problem they are rather business minded and quiet expensive. Moreover elderly people, who are particularly home-bound patients do not prefer custodial care and want to be at home where they are not detached from their family, friends and society.

When we analyze the diseases of the elderly we can see that many of the diseases that haunt them are chronic in nature. In many a case the detection and cure of these diseases require continuous monitoring of the physical parameters due to their special nature of occurrence. Other major issues affecting elders are bed-sore in case of bed-ridden elders and unintentional fall. Though there are many products available in the market today for monitoring patients we can see that many of them only measure individual parameters like heart rate, body temperature etc and many of them do not address the problem of tilt or fall and are not specific for elders.

Immediate and accurate health parameter detection and the quality of the system make HOPE a good choice for the elders. The system can efficaciously link the elder patients with the caregivers without much complexity. The backbone of the entire system is the mobile technology – mobile phones which are easily available and not much proficiency is required to operate the mobile phone, so it can be used easily by the elders. The mobile application is designed in such a way that the caretaker will have the clear picture of the present health condition of the patient.

II. Problem Definition

Projected increase in both the absolute and relative size of the elderly population in countries all over the world is a subject of growing concern. Along with the rise in the population of the aged there arises a need for better technology in monitoring their health. The proportion of elderly persons in the population of India rose from 7.5% in 2001 to 8.5% in 2010. The Indian aged population is currently the second largest in the world. As population ages, more demand is placed on caring for the elderly. The absolute number of the elderly (above 60 years old) population in India is projected to increase from 77 million in 2001 to 137 million by 2021.

Many of the elderly have various degrees of disabilities. They are often dependent on others for their activities of daily living. Some of them remain bedridden due to various causes. A person who is bedridden usually needs full-time care and attention. This means that a ‘Care Team’ (including family, friends, nurses and other professionals) will likely be working together. Because of this, it is important to make sure that every care team member keeps a written record of the elder’s health parameters. The healthcare provider may also be interested in a record of body temperature, pulse and respiration and they have to make sure that the position of the elder is changed periodically so as to reduce the possibility of bed sore. Clearly, in view of such a demographic trend, medical assistance to the rising number of dependent elderly is a major problem that many countries are facing now. In this scenario, a constant and reliable assistive technology which can cater the needs of these home bound elders is the need of the hour.

Assistive technology devices are basically helpful products that improve a person's ability to live and function independently. These types of assistive gadgets can also prove to be a boon to the care givers, since their workload can be drastically reduced.

III. RELATED WORKS

Some of the elder care systems as mentioned in [1] monitor activities of the elders in their home. They embed a video system in the living environment of elders and continuously monitor their activities at home. But this system doesn't measure any of the vital parameters of the elderly patient. Measuring the vital parameters is inevitable if the elder person suffers from any sort of heart ailments, which are very common in individuals aged above 60[11]. In [2] mobile devices like Caalyx (Complete Ambient Assisted Living Experiment) which can measure vital signs like ECG, pulse, Blood pressure, Movement and Fall detection. But the design we have proposed can monitor vital parameters and fall detection along with tilt monitoring for the bed ridden patients to monitor any case of bedsore. Some devices as in [3] monitor only fall detection for the elderly patients based on the sensor readings from accelerometers and microphones attached to the body of the patients. The system proposed in [4] is applicable to patients and elders for activity monitoring and fall detection and also sports athletes' exercise measurement and pattern analysis.

IV. SOLUTION

Our team members have conducted research on Elder Care at home and also regarding the latest trends in the field of assistive technology for elders. We had a telephonic conversation in August 2011 with a group of doctors in Amrita Institute of Medical Science (AIMS - one of the largest Multi Specialty hospital in India) including a Neurologist, a General physician and a Gerontologist to identify the most effective and convenient assistive device for elders. During the meeting the importance of monitoring simple vital parameters in diagnosing large number of diseases was discussed. Also the effect of cases like hyperglycemia and hypoglycemia on body temperature and heart rate were was discussed.

A sudden increase in the body glucose level could make the elder unconscious leading to an unintentional fall. Also the temperature has to be constantly examined to acquire information about maximum temperature, the time of the rise and fall of the body temperature etc. We also understood that the variation in the heart rate along with the body temperature was vital in diagnosing diseases like Malaria, Tuberculosis and Diarrhea. The doctors provided inputs on various cases of bedsores and expressed their concern on lack of a proper system for monitoring tilt of bedridden elders. These inputs were instrumental in the design of our device. Although there are many important devices for elder care by a number of pioneers who have blazed the way, we see our device is unique in its simple design and also in its implementation. It is typical for a device to have to make tradeoffs between breadth and depth. For example, if the device is universally applicable, it has breadth, but may lack depth because of its increased cost and lack of quality of the device and vice versa. So it is important to design a device which has both breadth and depth in its application.

V. SYSTEM DESIGN

For ease of understanding and explanation the complete system can be divided to three subsections.

a) *Medical Device System(MDS)*
b) *Central Controller Environment (CCE)*
c) *Mobile Application Module(MAM)*

A. *Medical Device System*

Medical device environment consists of sensors attached to the body of the patient. It comprises of the heart rate, temperature, tilt and fall sensor.

a) *Heart Rate Sensor*

Heart rate is the number of heartbeats recorded per minute typically recorded as Beats per Minute (BPM). In the proposed system, photoplethysmography technique (PPG) is used for obtaining the heart rate and not the conventional pressure sensing technique as in [5]. PPG is a simple and low cost optical technique that can be used to detect the blood volume changes in the micro vascular bed of tissues. In this technique, an IR led and a photo transistor is employed to detect the blood flow at the finger tip or any other peripheral part of the body. Here more light is transmitted through the tissues in case less blood flows through the blood vessels. This minute variation can be detected using the photo transistor and the voltage output can be suitably amplified manifold using an Op-amp and filtered using a diode and capacitor circuit. Thus we get the voltage variation corresponding to the blood flow through the tissues. The heart rate is related to the blood flow and is counted with the help of a microcontroller. A notch filter or low pass filter can be used for filtering.

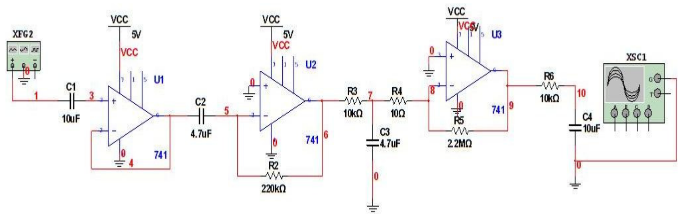

Figure 1. Circuit diagram for heart rate sensor.

The circuit diagram for the heart rate sensor is shown in Figure 1. This IR-LED phototransistor pair detects the blood flow through the tissues at the finger tip.

The voltage variation thus produced is very low with a signal peak-peak of 400mv. Also for different individuals we have a different dc-offset value at the output. To remove this dc offset we place a capacitor in series to the IR led phototransistor pair output. This signal is then passed through a differentiator which can detect the sudden fall in the PPG signal thus providing a suitable waveform for the peak detection. Then to remove the noise due to ambient light we place a low pass filter as in [9], with a cutoff frequency around 3Hz. We place a cutoff frequency of 3Hz because we consider the maximum heart rate to be detected as 200 beats per minute approximately. The filter output is passed through an inverting amplifier to provide the required amplification. The noise can distort the amplifier output which is taken care by placing a Low Pass filter at the output, with a cutoff freq of 10Hz to reject the noise due to ambient light and other interferences.

b) Temperature Sensor

The body temperature is an important measure in determining the health status of the patient. So the temperature sensor must be sensitive to even a very small rise or fall in the body temperature of the elderly. In the proposed system we use the IC DS1620, a Digital Thermometer and Thermostat, providing 9-bit temperature readings, which indicate the temperature of the device as in [8]. The IC is available as 8-pin DIP or SO package. A set of pre-defined commands are used for configuring and reading the temperature value from the sensor. Communication with the sensor is done via a three wire serial interface. No external components are required for the temperature measurements. It measures temperatures from -55°C to +125°C in 0.5°C increments, which is the required precision for a patient monitoring system. The temperature value of the patient is read using the Arduino Board at regular interval of time.

c) Tilt and Fall Detection

ADXL335 is a small, low power tri-axis accelerometer with signal conditioned outputs. This can measure static acceleration of gravity in tilt- measurement applications as well as dynamic acceleration measurements resulting from fall, motion or vibration.

ADXL335 has a measurement of ±3g which is as required for monitoring a bed-ridden elderly. This device is given an input voltage (Vs) of 3V with a sensitivity of ±300mV/g. The zero g bias is defined to be 1.5V (Vs/2). The x, y and z pins which gives the corresponding acceleration is connected to the three analog pins of the Arduino Board for further Analog to Digital Conversion (ADC) and processing.

Tilt is a static acceleration measurement and its variation will be around ±1g along the entire three axes. The Arduino Board uses its built-in ADC modules to convert these analog values to their corresponding digital equivalent and simultaneously monitor these values for a predefined time interval. It also checks whether these values falls inside a defined range of values. If it does so it indicates that the elderly patient has been lying at that position for some considerable time and the position has to be changed for avoiding cases of bedsore. So the device triggers its alert mechanisms for notifying the medic or caretaker. Similarly a fall is detected by continuously monitoring the x, y and z pins for abrupt or abnormal changes in g values. Unlike the sensors deployed in shoes as in [6] the accelerometer is attached to the main body, preferably at some areas near chest.

B. Central Controller Environment(CCE)

CCE consists of an Arduino Duemilanove Board as in [10] and Bluetooth module for interfacing all the sensors with the mobile phone. The Bluetooth module, which is the stackable shield place over the Arduino Board, makes the system compact, simple and wireless. The Arduino Board is pre-programmed to collect the analog data coming from the sensors followed by their conversion to its corresponding digital value. It also takes care of the digital communication protocol necessary to communicate with the temperature sensor. These digital equivalents of the vital parameters are serially transmitted to the Bluetooth shield for its wireless transmission to the mobile phone.

C. Mobile Application Module(MAM)

Any basic model of cell phone with Bluetooth facility and application software support can be used. The cell phone basically collects the data via Bluetooth, processes it and sends it for expert's review. It also triggers the alert mechanisms in case of emergencies. The application software developed will be customizable and will have provision for the medic to specify the critical limits and values beyond which the alert mechanism has to be triggered.

VI. SYSTEM ARCHITECTURE

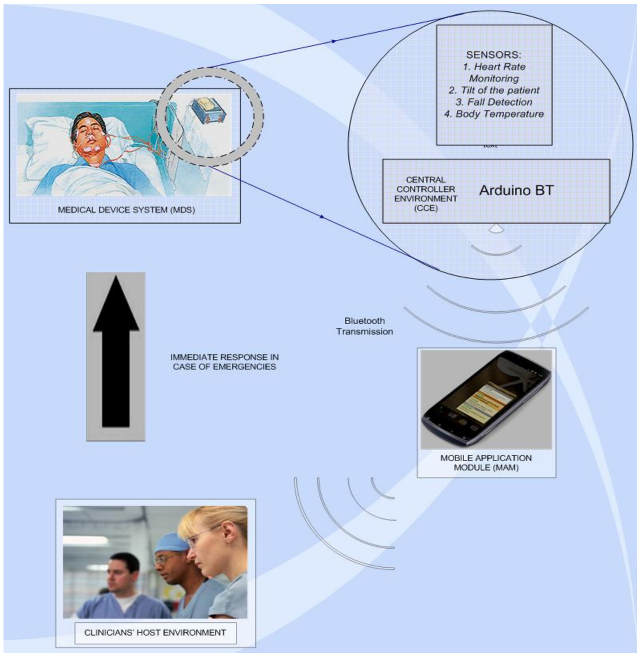

Figure 2. System level diagram

The block diagram the as in Figure 2 shows the sensors connected to the elderly patient and they measure the heart rate, body temperature, tilt and fall of the patient. The sensor readings are recorded in the Central Controller Environment (CCE). Then the data is processed and the values are sent to his/her Smartphone. Any emergency condition like a fall or abnormal heart rate is informed to the caretaker by sending an alert to his/her Smartphone as SMS, MMS or a voice call so that the caretaker can attend to the patient immediately.

VII. ALGORITHM

As shown in the figure system monitors the heart beat, body temperature, tilt and fall of the patient. All the sensors are made compact and integrated into a small unit, so that the system will be portable .To avoid the muddling up of the three sensor outputs and unnecessary wastage of memory in mobile phone data is not send continuously from the IWC instead a time slot is allocated for the transmission of data to the mobile phone. We send the data of the body temperature in a time interval of 15 minutes; heart beat every 10 minutes and tilt/fall pressure every 5 minutes. This database in the mobile phone can be used by the medic for future references for getting the correct picture of the physiological conditions of the patient. The vital parameters are also send whenever there is an abrupt or abnormal deviation of the physiological parameters from an optimal value. This may not follow the general transmission procedure of timeslot and this can triggers the alert mechanisms developed using the application software.

VIII. FLOWCHART

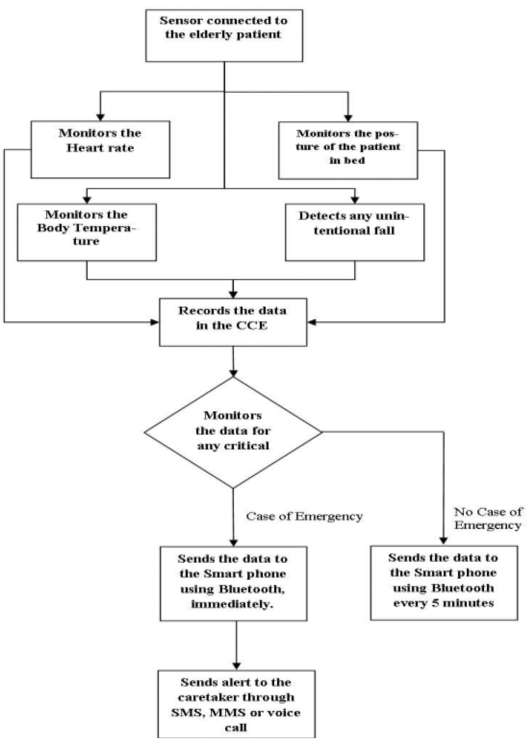

Figure 3: Control flow diagram

The flow diagram shown in figure 3 shows the control flow of the proposed system. The four sensors heart rate, temperature, tilt and fall continuously monitors the physiological conditions of the patient and the data collected is transferred to the CCE which contains of Arduino Board which process the information and check for any critical situations CCE also contains a Bluetooth shield which transfers the data to the mobile phone. If there is no case of emergency CCE sends data to the mobile phone on a time basis so that unnecessary data accumulation does not take place. This database can be used by the care team for future references. If there is a case of emergency the data is send immediately so that it triggers the alert mechanism to the care taker through an SMS, MMS or voice calls.

IX. TEST RESULTS

The heart rate measurement was done for six subjects. The measurement for a single person is shown in Table 1. The average measurement for other individuals is given in Table 2. The heart rate measurement was initially done using the system and it was compared against the manually measured heart rate.

A. Heart Rate

Six readings were taken simultaneously from an individual subject using PPG and manual means and the results obtained are summarized in the table 1.

TABLE I. HEART RATE MEASURMENT OF INDIVIDUAL SUBJECT

S.No	**Heart rate using PPG method (*in beats per minute*)**	**Heart rate measured manually (*in beats per minute*)**
1	60	62
2	62	64
3	62	64
4	60	66
5	62	66
6	60	64

The results obtained in Table 1 are shown graphically in figure 4.

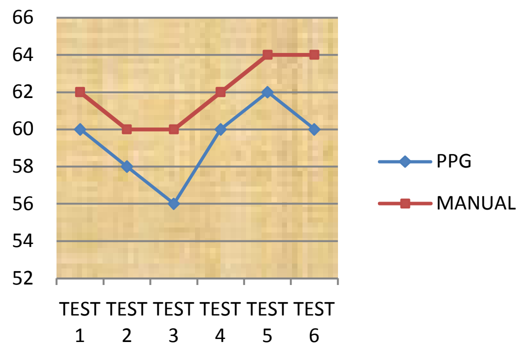

Figure 4. Graphical representation of Table 1.

The above procedure of measuring heart rate was conducted for 6 subjects and their averaged heart rate calculated manually and using our system is demonstrated in the table below.

TABLE II. AVERAGED HEART RATE OF SIX SUBJECTS

S. No	Heart rate using PPG method (*in beats per minute*)	Heart rate measured manually (*in beats per minute*)
1	61	64
2	72	75
3	76	79
4	72	75
5	72	78
6	73	76

Graphical representation of Table 2 is shown in figure 5.

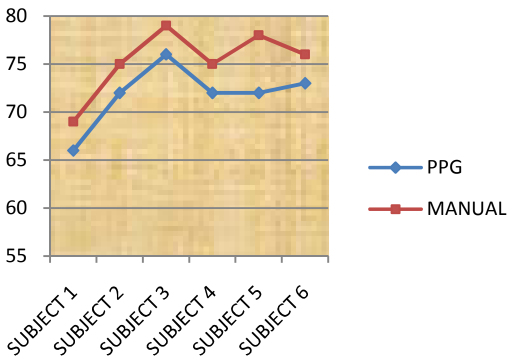

Figure 5. Graphical representation of Table 2.

B. *Temperature:*

Temperature sensor was tested two times for a subject using DS1620 temperature sensor IC and digital thermometer. The above procedure was repeated for four subjects and the averaged results are summarized in table 2.

TABLE III. AVERAGED TEMPERATURE READING OF FOUR SUBJECTS

S.No	Temperature (°F)	Temperature measured using Thermometer(°F)
1	97.2	96.5
2	96.3	94.5
3	97.2	96.9
4	97.2	95.3

The result obtained in Table 3 is represented graphically in figure 5.

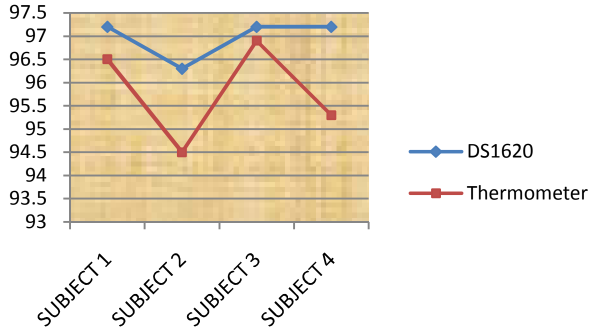

Figure 6. Graphical representation of Table 3.

C. *Tilt and fall detection*

The fall detection was tested by dropping the accelerometer from different heights and monitoring the values at its x, y and z pins. The accelerometer reading for altitude of 40cm and 50 cm are shown below. The accelerometer readings are in terms of 'g' (g-force). There are three regions mentioned in the sensor readings, the initial stable region, the free fall region and the impact region. The values coming in stable region can be used for measuring tilt and the values in free fall and impact region can be used for detecting a fall.

TABLE IV. ACCELEROMETER READINGS FOR VARIOUS TEST CASES

For free fall from height of 50cm(Test 1)		
Initial reading	Free fall reading	Reading at mpact region
Tilt measure X=0.04	Tilt measure X=-0.02	Tilt measure X=-1.29
Tilt measure Y=0.06	Tilt measure Y=-0.04	Tilt measure Y=0.72
Tilt measure Z=1.05	Tilt measure Z=0.04	Tilt measure Z=-0.52

Tilt measure X=-0.15	Tilt measure X=-0.15	Tilt measure X=-0.19
Tilt measure Y=0.12	Tilt measure Y=0.01	Tilt measure Y=-2.47
Tilt measure Z=-0.10	Tilt measure Z=0.12	Tilt measure Z=2.78
Fall Detected		

For free fall from height of 50cm(Test 2)		
Initial reading	Free fall reading	Reading at mpact region
Tilt measure X=-0.13	Tilt measure X=0.02	Tilt measure X=-0.60
Tilt measure Y=0.06	Tilt measure Y=0.01	Tilt measure Y=-0.46
Tilt measure Z=0.97	Tilt measure Z=0.06	Tilt measure Z=-1.68

Tilt measure X=-0.08	Tilt measure X=-0.13	Tilt measure X=-0.16
Tilt measure Y=0.15	Tilt measure Y=-0.05	Tilt measure Y=1.12
Tilt measure Z=0.06	Tilt measure Z=0.07	Tilt measure Z=-0.25
Fall Detected		

For free fall from height of 40cm(Test 1)		
Initial reading	Free fall reading	Reading at mpact region
Tilt measure X=-0.22	Tilt measure X=-0.13	Tilt measure X=1.20
Tilt measure Y=-0.21	Tilt measure Y=0.06	Tilt measure Y=-0.05
Tilt measure Z=1.02	Tilt measure Z=0.06	Tilt measure Z=0.46

Tilt measure X=0.75	Tilt measure X=-0.16	Tilt measure X=-0.08
Tilt measure Y=0.13	Tilt measure Y=-0.08	Tilt measure Y=0.95

Tilt measure Z=0.26	Tilt measure Z=0.07	Tilt measure Z=0.30
Fall Detected		

For free fall from height of 40cm(Test 2)		
Initial reading	Free fall reading	Reading at mpact region
Tilt measure X=-0.27	Tilt measure X=-0.13	Tilt measure X=-0.30
Tilt measure Y=-0.04	Tilt measure Y=0.04	Tilt measure Y=-1.25
Tilt measure Z=0.85	Tilt measure Z=0.07	Tilt measure Z=2.76
Tilt measure X=-0.46	Tilt measure X=-0.18	Tilt measure X=2.04
Tilt measure Y=-0.38	Tilt measure Y=0.12	Tilt measure Y=0.15
Tilt measure Z=0.13	Tilt measure Z=0.04	Tilt measure Z=-0.04
Fall Detected		

X. CONCLUSION

Providing quality and timely health assistance for elderly population is a growing concern of both developed and developing nations. Though there are high-tech hospitals and care centers for elderly the fact that majority of them suffer from chronic disease and they require continuous monitoring of their physical parameters make it quiet expensive. Moreover majority of the elderly prefer to be at home where they are not detached from the family and society.

In such a scenario the proposed model could be really effective. It can work independently at a home environment. Beyond measuring the vital parameters, this system has uniquely addressed the special case of tilt and fall detection in order to prevent the cases of bed sore, which is of utmost importance to the bed-ridden elderly. Thus this device can really be a boon to them by assisting the elderly in getting quality assistance at their own houses.

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