Wireless gadget for Home Bound Patients (using IEEE Standard 1073 for Medical Device Communications)

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Abstract— **Improving the quality of life for the elderly persons and giving them the proper care at the right time is the responsibility of the younger generation. Due to lack of awareness on proper elder care, unavoidable busy schedule etc. the elderly population is seem to be quite ignored. To address these problems, we are trying to find an amicable using a compact and user friendly system design. A constant and reliable assistive technology is essential while taking care of home-bound patients. The case is even worse when they are bedridden. Several health problems along with their various disabilities will make the situation much more horrid. This is where they need extra care and attention from their care providers. This includes the holistic welfare of their health. 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. A gadget, complying with IEEE Std. 1073, that can solve all these problems together will be a boon to the home-bound bedridden patients.**

Index Terms— **Elder care, home-bound patient, Assistive technology.**

INTRODUCTION

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

Analyzing 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. Another major issue affecting bed-ridden elderly is the case of bed-sore and unintentional fall as in [1]. Though there are many products available in the market today for monitoring patients as in [2], we can see that many of them only measure individual parameters like heart rate, body temperature etc. Also, many of them do not address the problem of tilt or fall.

HEALTH PARAMETERS AND IEEE STD

Immediate, accurate health parameter detection and the quality of a system make it a superior choice among the monitoring systems, which are available in the market today. This 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 that are easily available. In this mobile phone era, there is not much proficiency required to operate them, even by the elders. The mobile application is designed in such a way that the caretaker has the clear picture of the present health condition of the patient as explained in [3].

While designing the whole system, a proper standard has to be used in order meet the quality and technology needs. For that purpose we use IEEE Standard on Medical Device Communication (IEEE Std 1073-1996). This standard mainly describes the interconnection and interoperation of medical devices with computerized healthcare information systems in a manner suitable for the clinical environment (*Excerpt From the standard: "Medical devices include a broad range of clinical monitoring, diagnostic, and therapeutic equipment. Computerized healthcare information systems similarly include a broad range of clinical data management systems, patient care systems, and hospital information systems"*). The standard has a close relationship with the gadget or in other words the standard itself is realized in such a way that most of the emerging technologies are incorporated in it for the total system effectiveness and improved functionality. The standard gives detailed description on the specifications of the devices to be used, the reference model, the communication standard, and information and implementation models. The system we designed is in compliance with all the requirements of the standard, starting from the bedside environment description to the implementation model.

SYSTEM ARCHITECTURE

The block diagram in Figure 1 shows the sensors attached to a home bound elderly patient. They measure the heart rate, body temperature, tilt and fall of the patient. The sensor readings are recorded in the Central Controller Environment (CCE). Those readings are processed and the data is sent to the patient's Mobile phone/Smartphone. Any emergency condition like a fall or abnormal heart rate is informed to the caretaker by sending an alert to the caretaker's Smartphone as SMS, MMS or a voice call so that the caretaker can attend to the patient immediately.

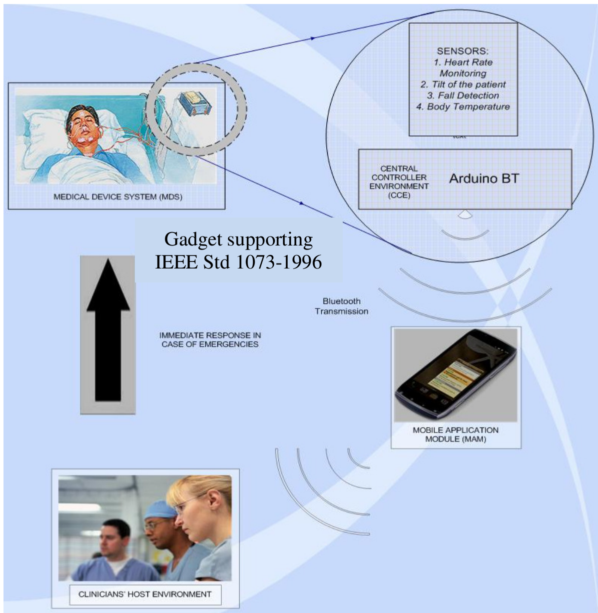

Figure 1. System Architecture Diagram

SYSTEM IMPLEMENTATION

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 our system, photoplethysmography technique (PPG) is used for obtaining the heart rate and not the conventional pressure sensing technique as in [4]. 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.

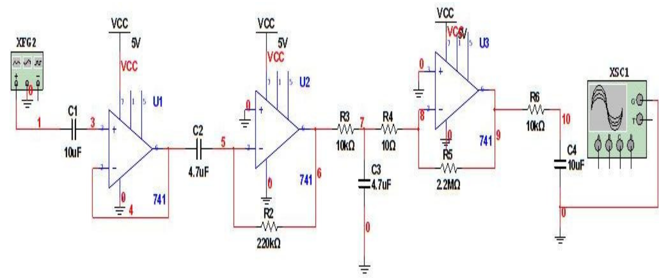

Figure 2. Heart Rate Detection Circuitry

The circuit diagram for heart rate detection is shown in the Figure 2. This IR-LED phototransistor 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 various patients, 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 due to ambient light and other interferences can distort the amplifier output. This is taken care by placing a low pass filter at the output, with a cutoff freq of 10Hz.

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. For this system we used the IC DS1620 as in [7], a Digital Thermometer and Thermostat, providing 9-bit temperature readings, which will clearly indicate the temperature of the patient. 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.
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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. In this case the device triggers its alert mechanism 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. In contrary to the setup described in [7] this model uses simple Bluetooth interface for communicating the accelerometer values with the remote processor. In our system this accelerometer is kept near chest and not in shoes as described in [8].

B) Central Controller Environment (CCE)

This is one of the important modules of this health-care gadget. It consists of an Arduino Duemilanove Board 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 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)

This module forms the soul of our patient monitoring system. 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 is customizable and has provision for the medic to specify the critical limits and values beyond which the alert mechanism has to be triggered.

THE IEEE 1073 STANDARD

The primary purpose of the IEEE 1073 series of standards is to provide a consistent communication model across the vast area of medical devices, systems, and sub-systems. To achieve this it is necessary to provide a detailed description of the various medical devices along with the modeling technique used to describe these devices. The interoperability of these medical devices in the patient bedside environment, primarily between the bedside and the patient care information systems, will play a major part in the future of medical informatics.

The IEEE Standard 1073 supports our requirement to interface medical instrumentation with computerized health care information in an acute care or clinical environment. This standard takes in to consideration both simple and intelligent devices which are devices of current clinical engineering technology.
As far as we are considered we are dealing with the following aspects of Medical Standard 1073

- Automation and recording of data from medical devices.
- Providing adequate medical assistance from the medic in case of critical changes in device status.

As denoted in IEEE 1073 standard the devices that are interfaced using these aspects, are mainly used for physiological parameter measurement, monitoring devises and data entry devises.

THE IEEE 1073 STANDARD IN OUR SYSTEM

As in the case of any typical clinical environment for monitoring the physiological parameters of an elderly patient, sensors of the gadget for detecting temperature, heart rate, tilt and fall are attached to the patient's body. These sensors (or medical devises) exchange information with a processor (Arduino Duemilanove) located at the bedside environment, which automatically collects and process the data from the sensors. The medical devices and remote processor works in a synchronized manner to form the Medical Devise System (MDS). Information collected from MDS are sent to a remote processor (geographically remote relative to the physical bedside location which is an Android Mobile phone), via Bluetooth (non IEEE 1073) for its wireless transmission to Medic.

ALGORITHM SUPPORTING IEEE 1073 STANDARD IN OUR SYSTEM

As shown in the Figure 3, 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 sent continuously from the CCE. Instead, a time slot is allocated for the transmission of each of the sensor's data to the mobile phone. This is in accordance with the Standard 1073 where a consistent, time bound data transfer takes place using the Bluetooth communication interface between the sensors and the mobile phone.

The body temperature data is sent in a time interval of 15 minutes; heart beat data every 10 minutes and tilt/fall data every 5 minutes. This data is stored in the mobile phone, which 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 sent to mobile phone without complying with these timing intervals, i.e. whenever there is an abrupt or abnormal deviation of the physiological parameters from an optimal value. This cannot follow the general transmission procedure of timeslot and this can trigger the alert mechanisms developed using the application software. This is in exact compliance with the Medical Standard 1073 where in automation and recording of data from medical devices is required. Also another aspect of the standard, which states that 'providing adequate medical

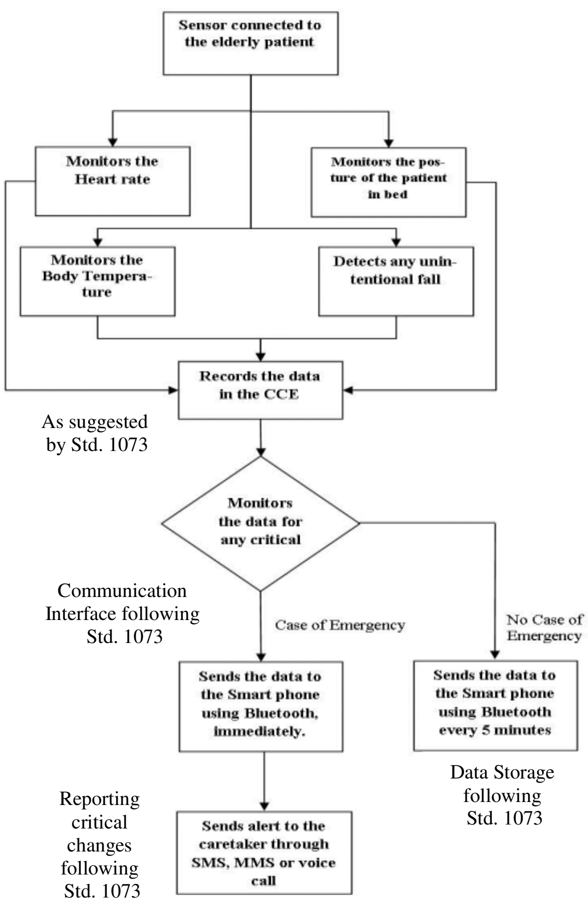

Figure 3. System Flow Chart

The flow diagram in Figure 3 shows the control flow of this system. The sensors - heart rate, temperature, tilt and fall, continuously monitors the physiological conditions of the patient.

The data collected from these sensors via CCE which contains Arduino Board, processes the information and checks for any critical condition. As per the Std 1073 there should be a consistent communication model across medical devices. All the sensors communicate to Arduino board with customized interfaces. The heart rate sensor is interfaced to the Arduino via analog input whereas the temperature, tilt and fall sensors via digital inputs.

CCE also contains a Bluetooth shield that transfers the data to the mobile phone. Bluetooth is itself defined by IEEE standard protocol and we use it for the communication interface between the CCE and mobile phone. If there is no case of emergency, CCE sends data to the mobile phone on a timely basis so that unnecessary data accumulation does not take place. The care team uses this database for future research and analysis. This feature also complies with IEEE Std. 1073.

In case of emergency, the data is sent immediately notwithstanding the time duration as explained earlier, so that the gadget triggers the alert mechanism through an SMS, MMS or voice call, to alert the caretaker. Providing adequate medical assistance from the medic in case of critical changes in device status is also one of the features of IEEE Std. 1073 which is supported in our system.

Medical Device Data Language

As in the case of Medical device data language (MDDL) explained in IEEE standard 1073, the message we use for communication contains medical data and variable amount of contextual information to interpret data. For example if temperature value is being transmitted from medical device system to a remote processor, sixteen bits are allocated from the actual bandwidth. The first 8 bits denote the prefix added to indicate a temperature value that is being sent and the last 8 bits denote the temperature value. Obviously, the first eight bits of the sixteen-bit data for temperature, heart rate, tilt and fall parameters will not be identical. This MDDL is used for providing powerful capabilities for defining and conveying contextual information regarding the clinical measurements and the state of the system.

As specified in the standard, the system uses a "plug it in and walk away" mode of communication, which is robust, reliable and adaptable to a clinical environment. As described earlier the sensor module together with the processor forms the medical device system. Once this device is powered, it functions independently, unaffected by the conditions of other elements implemented in the circuit. Here the Bluetooth module associated with the processor forms the Device Communications Controller (DCC). DCC forms the interface for MDS in the bedside environment on the android phone which collects the information passed from the MDS. Here, all connections are initiated by MDS through its DCC. The functionality of Bedside Communication Controller (BCC) as specified in the Standard is achieved using an android mobile phone. The BCC is the physical point of connection for DCCs whose MDSs need to be associated with a specific bedside environment. The BCC is the specific entity that associates those MDSs connected to it with the particular bedside environment for which it has been configured. It functions as a gateway between those MDSs connected to it and a PCS desiring to exchange messages with those devices.

TEST RESULTS

Heart rate measurement was done for six subjects. It was initially done using the system (PPG technique) and it was compared against the manually measured heart rate. Error percentage was calculated from these readings and the maximum and minimum error percentage was found to be 6.94% and 3.95% respectively. The test results are shown in Table 1.

Four subjects were used to test the temperature sensor DS1620. These measured values were compared with a digital thermometer value and the error percentage was calculated. The thermometer used for this purpose was OMRON MC-246. The maximum and the minimum error rate of the temperature sensor were found to be 1.95% and 0.30% respectively. This is demonstrated in Table 2.

For testing fall detection using accelerometer, the accelerometer was dropped from a height of 50 cm. It was found that irrespective of the initial reading of the accelerometer, during free fall, it showed nearly zero g-force at all the three axes. Also the readings were above 1.2 g-force at the region of impact. Thus the algorithm of detecting free fall and impact region worked correctly in all cases of unintentional fall. The obtained results are shown in Figure 4.

TABLE 1

Subject no:	Percentage error calculation in the heart rate of six subjects Type Styles		
	Heart rate using PPG method (in beats per minute)	***Heart rate measured manually (in beats per minute***	Error percentage (In %)
1	61	64	4.92
2	72	75	4.16
3	76	79	3.95
4	72	75	4.16
5	72	78	6.94
6	73	76	4.10

TABLE 2

Subject no:	Error percentage in temperature reading of four subjects		
	Temperature measured using DS1620 (°F)	***Temperature measured using Thermometer(°F)***	Error percentage (In %)
1	97.2	96.5	.72
2	96.3	94.5	1.87
3	97.2	96.9	.30
4	97.2	95.3	1.95

Case 1: For free fall from height of 50cm

1st test

Initial Reading	Free Fall Reading	Reading at Impact 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

2nd test

Initial Reading	Free Fall Reading	Reading at Impact 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

Figure 4. Accelerometer output for unintentional fall from height of 50 cm

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 this system could be very 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. The device complies with IEEE Standard 1073 features like: consistent communication model across medical devices, automation, and recording of data from medical devices and providing adequate medical assistance from the medic in case of critical changes in device status etc. Thus, this device can really be a boon to elderly society by assisting them in getting quality assistance at their own houses.

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