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Human Activity Monitoring System with Wearable Sensors Integrated into Apparel

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Abstract: Nowadays, elder people suffer a lot from chronic diseases. People who suffer from chronic diseases, they need to repeatedly visit the hospital and check the vital signs periodically. Asthe health care cost is increasing, people cannot afford to go to hospital regularly. There has been a need to monitor a patient continuously from a remote location even without hospitalization with accuracy. For this, wearable sensors are embedded into apparel. This smart shirt is worn by both inpatients and outpatients and patient's vital signs are continuously monitored over a long period of time and the values obtained from the sensors are compared with the threshold set by clinicians. If any abnormal condition is detected, an alarm is issued and the results will be displayed in computer. And also the collected data is sent securely via zigbee to the clinician who is taking care of that patient for further analysis. At the medical centre the patient details are stored in database and the data is published in intranet. Based on the clinician advice, patient will visit doctor. In addition the system can also send symptoms, causes and medicines to a patient in remote places from medical centre. Consequently, vital-sign monitoring systems will reduce health-care costs by early disease detection/prevention and enhance the quality of life of patients.

Index Terms: Zigbee; Smart Shirt; Healthcare; Wearable Sensors; Vital Signs.

1. INTRODUCTION

Although, India will be the youngest country in the world by 2020 with a median age of 29 years. According to the non-profit organization report, the number of elderly people is likely to increase significantly after 2020. By 2021, the elder people count is 143 million. The elder citizen may suffer a lot. With the lack of immediate help, they may go through stress and dehydration. We will pay more attention to take care of senior citizen healthcare and make them happy.

Advances in sensor and connectivity technology are allowing devices to collect record and analyse data. In healthcare, able to collect patient data over long time that can be used to help enable preventive care, allow early diagnosis of diseases. IoT related healthcare systems are based on the Internet of Things as a network of devices that connect directly with each other to capture and share vital data through a wireless communication (Zigbee) and store the data in server. IoT systems are making to reduce costs and improve health by increasing the availability and quality of care[8].

Advancements in pervasive computing, coupled with microelectronics have created opportunities for the integration of electronics and flexible sensors. These flexible sensors are embedded into apparels are referred to as e-textiles or smart textiles. Smart materials sense and react to environmental conditions. The intelligence of textiles may be passive, active or very smart. A passive textile only acquires information about the environment. Active textile acquires and reacts to its environment. And very smart textiles be context-aware and adapt their responses based on the context.

There are two approaches to the fabrication of garments with sensor[6,7]:

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- Finished garments—Integration of finished garments with sensor elements. Sensor has fitted in the small piece of elastic apparel. And then we have to stitch these apparel into smart shirt in appropriate location.
- Unfinished garments—Embedded the sensor in garment fabrication process. In this type, sensors can't be removed from the apparel.

Smart shirt should be light in weight so that it is comfortable to wear 24/7 and also consume low power. In this remote monitoring system, smart shirt is used to monitor vital signs of a patient.Vital signs are measurements of body basic functions.We monitor the room temperature, body temperature, heart rate and blood pressure.

Our human body temperature depends on environment temperature. Body temperature is slightly high in noon time. And also we have to maintain an environment temperature cooler than our body temperature. Heart rate will rise in hot temperatures, and lower in low temperatures. Blood pressure will rise in cold temperatures, and lower in hot temperatures.We hypothesized that heart rate would be directly proportional to temperature and blood pressure would be inversely proportional to temperature.

2. RELATED WORK

Wearable physiological monitoring system consists of an array of sensors embedded into fabric of wearer to continuously monitor the physiological parameters & transmit wireless to a monitoring system. Here sensors are embedded in unfinished garments. So, repositioning of sensor in the fabric is difficult once integrated[5].

Developed bedridden patient monitoring system, compare patient readings with prescribed values & interacting with medical staff. Heart rate, blood pressure and temperature sensors are used to monitor vital signs of patient. The disadvantage is wiring connections are explicitly shown [4].

Designed a low cost biomedical sensor interface for patient monitoring system & send the data through mobile phone network assisted by GSM/GPRS modem. Temperature and pressure sensor are used here. Here, low cost sensors are used so got low accuracy[3].

Real time health condition of a patient is send to a patient monitoring system through Zigbee, which can be used by healthcare professionals. System generate an alarm message for patient abnormal condition. Temperature, heart rate and ECG sensor are used here. Normally in a patient monitoring system, blood pressure monitoring is important. Here blood pressure sensor is missed[2].

3. PROPOSED WORK

We propose a remote health monitoring system for both inpatient and outpatient. Patient who suffer from diseases wear a smart shirt. Figure 1represents the smart shirt. The smart shirt is embedded with sensors which continuously monitor the vital signs of a patient. The data is transferred to medical center via zigbee. And the data is published in intranet. This system has rich Graphical User Interface. In remote places, compare the data obtained from the sensor with the threshold set by clinicians. And in medical center, storethe patient details for further analysis. In addition to this the system can send causes, symptoms and medicine to the patient which helps to prevent early disease.To implement the system in real time, *w* choose arduino microcontroller. And the sensors used are room temperature, body temperature, heart rate and blood pressure. Figure 2 represents the architecture of the system.

3.1. Data Acquisition

To acquire physiological data from the patient, we use body temperature, heart rate and blood pressure sensors. Arduino boards are able to read input from sensors and turn it into an output. This is defined by a

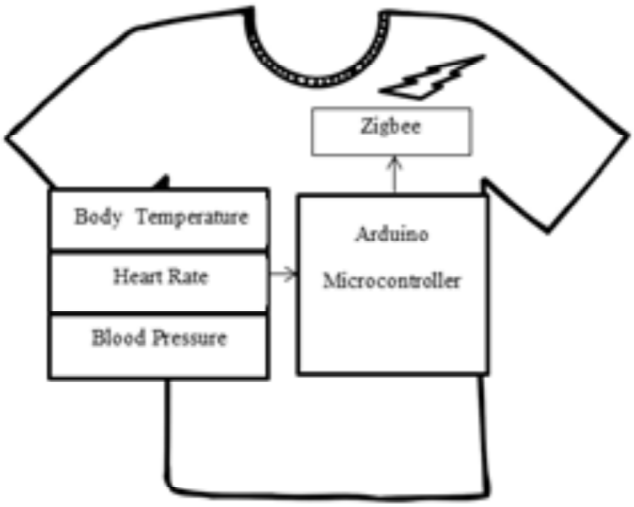

Figure 1: Smart Shirt

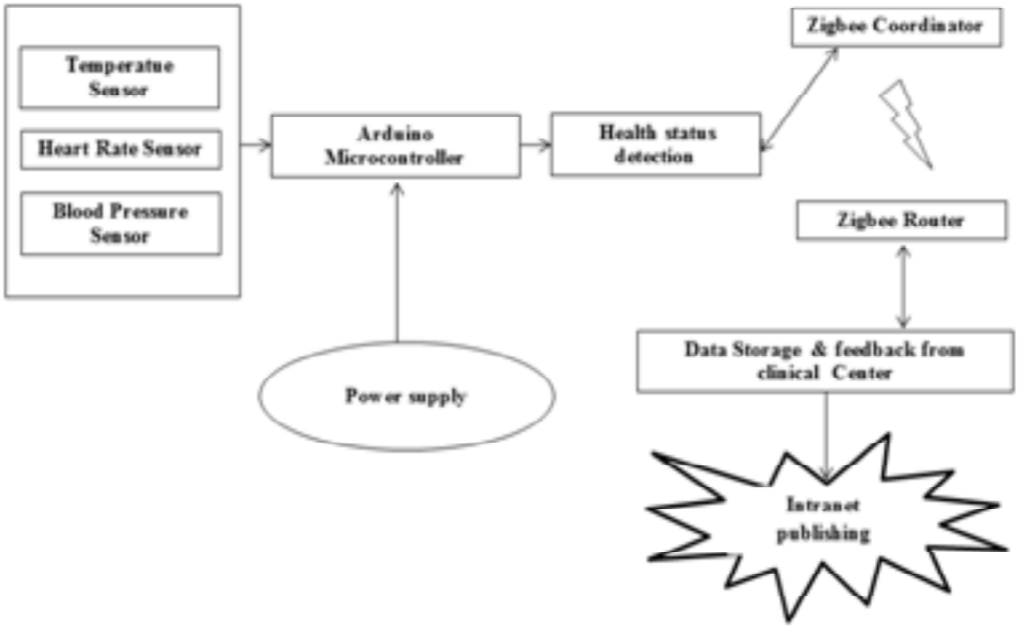

Figure 2: Human Activity Monitoring System

set of instructions programmed through Arduino IDE. Arduino ATMEGA has 54 digital and 16 analog input/output pins. We can give 6-20V voltage. It has 256KB flash memory and it has 10 bit Analog to Digital converter.

3.1.1. Room Temperature

The LM35 is temperature sensor, whose output voltage is linearly proportional to the celsius temperature. The LM35 sensor accuracy is ±1D 4°C. The range of the temperature sensor is –55 to + 150°C. The output from the sensor gives the analog voltage. This output is linearly proportional to the celsius (centigrade) temperature. Every 10mV is considered as 1°C. So divide the output mV by 10 gives the temperature value in °C.

3.1.2. Body Temperature

Temperature is a measure of the degree of heat intensity. The human body's core temperature varies from day to day, and from time to time, but these fluctuations are not more than 1ºC. The normal human body

temperature is 37ºC ±1ºC. There is a small almond shaped hypothalamus in the brain and takes control over the temperature changes in the body. The body temperature slightly changes on external and internal heat. A thermistor gives temperature by a change in electrical resistance. The thermistor gives only voltage value and not a resistance value.

By using voltage divider circuit to convert the voltage value into resistance value. The voltage divider circuit is shown in Figure 3.The voltage divider has two resistors in series. The upper resistor in the thermistor is variable resistance Rt. The lower resistor in the thermistor is fixed resistance R. A voltage Vs is applied to the circuit. The output voltage Vo depends on Vs and R, which are known, and Rt, which is variable and unknown. The thermistor gives the Vo voltage value.

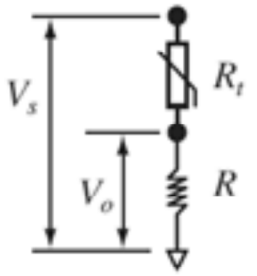

Figure 3: Voltage Divider Circuit

$$R_t = R(\frac{v_s}{v_o} - 1) \tag{1}$$

Equation (1) is used to compute the thermistor resistance from the measurement of Vo.Use Steinhart-Hart equation to translate resistance value to temperature value.

$$1/T = A + B\ln(R) + C(\ln(R))^3 \tag{2}$$

A, B & C are Steinhart-Hart parameters, R is resistance in ohms & T is temperature in kelvin. Temperature value is calculated from equation (2). Then convert kelvin to celsius & celsius to farenheit.

3.1.3. Heart Rate

Finger measuring heart beat sensor is used to measure heart rate. The sensor consists of phototransistor and IR LED. The finger is inserted in between phototransistor and IR LED. The infrared rays from IR LED is passed into the finger and the reflected into photo transistor. Each pulse is detected by a photo transistor and the sensor gives the number of pulses.

3.1.4. Blood Pressure

It measures the force of blood inside the blood vessel. Measurement shows how well the heart is working.SPD (Smart Pressure Device) is a silicon based pressure sensor. Pressure sensors are available in two operation modes namely gauge type and absolute type. In gauge type pressure sensor, there is a small vent on the package for getting contact with the atmosphere. In absolute type, vacuum is present. The sensor used here i.e. SPD015G is a gauge type sensor.

An instrumentation amplifier based on quad opamp LM324 is used for conditioning the output voltage from the pressure sensor. The cuff is placed in the left arm and then connected to the pressure sensor vent.

3.2. Health Status Detection

The sensor data are collected and compare the data with the threshold set by clinicians beforehand to generate the health status. If there is any mismatch occurs, system generates an alarm message.

The room temperature normal range is 22ºC to 26ºC. If it is less or greater than this value, patient may suffer from fever or sleep apnea. So, we have to adjust the thermostat to maintain the normal room temperature. There may be a relationship between room temperature and body temperature. So, we measure the room temperature also.

Body temperature of a patient varies from day to day and time to time. Normal body temperature of a person is 95ºF to 98ºF.

Normal heart rate of a person varies from 50bpm to 100bpm.The heart beat rate varies for different person. Infants, toddlers, Preschoolers, Adults and athletes have different heart beats. As human body temperature increases, heart beat also increases.

There are two types of blood pressure measurement. One is systolic blood pressure and the other one is diastolic blood pressure.When the heart ventricles contract, driving out blood from heart called systolic blood pressure. When the heart is relaxing, the ventricles are refilling the blood called diastolic blood pressure. Normal blood pressure of a person is 120/80.There are many stages of blood pressure range. It is classified as hypertension and prehypertension. As human body temperature increases, blood pressure decreases.

3.3. Wireless Transmission

Wireless communication realizes the transmission of information to medical centre. Zigbee protocol (IEEE 802.15.4) is used for communication. It has low data rate, very low power, long battery life and its range is 100m. The name ZigBee is said to come from domestic honey bee which uses a zigzag type of dance to communicate important information to other member's.

Zigbee has three different types of nodes,

- Zigbee Coordinator – Network creator. Only one coordinator in an each network and contains all information about the node.
- Zigbee Router – Router. Intermediate node and relaying data from other nodes.
- Zigbee enddevice – Low power. Functionality to talk. to their parents only. It can't relay data from other nodes.

3.4. Data Storage and Feedback From Clinical Centre

In medical centre, web application is created.To store the health status of a patient in medical centre. Based on abnormal situations, give a warning message to patient through Zigbee and thereby patient visit the doctor. In addition to these the system may give causes, symptoms and medicines also. The health status of a patient is stored in database and the data is useful for further analysis.

3.5. Intranet Publishing

Create a web services using wamp server. Here, we can make a database record to see all the doctors in a hospital. The database data may display in XML or JSON representation.

3.6. Results And Discussion

3.6.1. Experimental Setup

The body temperature sensor is fitted in an armpit position in a smart shirt. The heart rate and blood pressure sensors are wearable sensors which is fitted in a glove and attached with the shirt.Table 1 shows the values of room temperature, body temperature and heart rate. The values are measured at different times in a day. From this, we know that as the body temperature increases and also the heart rate also increases. And the body temperature slightly depends on room temperature.

And store the sensor data in mysql databases in a remote places and remote places has rich GUI Interface. Figure 4 respresents the remote place GUI environment.

Then the data are transmitted from remote places to hospital using Zigbee. And then in hospital/medical centre, the data is stored in mysql database in a wamp server. Then the data is displayed in a web application and published JSON representation in Intranet. Figure 5 Shows the JSON representation.

3.6.2. Performance Analysis

To measure the performance of the system, we have to use a percentage error measure. It is the difference between an approximate or measured value and an exact or known value expressed as percentage.

Table 1
Values of Room temperature, Body temperature and Heart rate at different times in a day

Time	Room Temperature (°F)	Body Temperature (°F)	Heart Rate (bpm)
6–7 A.M	32.20	95.72	60
	32.70	96.63	63
7–8 A.M	32.90	96.76	63
	33.20	97.59	65
10–11 A.M	33.80	97.19	65
	34.56	97.22	65
12–1 P.M	38.04	97.07	67
	39.55	98.03	70
1–2 P.M	39.71	97.18	68
	39.20	97.33	65
4–5 P.M	39.55	96.28	65
	37.60	96.11	62
5–6 P.M	31.74	95.38	63
	31.25	96.04	63
8–9 P.M	30.71	97.03	66
	30.23	96.51	64
9–10 P.M	30.64	96.68	63
	30.51	96.20	63

Figure 4: Remote Place GUI Environment

$$\% \text{ error} = (\text{approximate value} - \text{exact value}) \times 100\% \quad (3)$$

The performance analysis of body temperature and heart rate is shown in Table 2. The performance analysis of blood pressure is shown in Table 3.

[{“pid’’:”p1",”name”:”raji”,”address”:”37, pallikoodam street, apk”, “roomtemp”:”30",
“bodytemp”:”97",”heartrate”:”68",”sysbp”:”126",”diasbp”:”79},{“pid”:”p2",”name”:”thanam”,”address”:”45",
pallikoodam street, apk”, “roomtemp”:”28",
“bodytemp”:”96",”heartrate”:”65",”sysbp”:”130",”diasbp”:”82"}]”

Figure 5: JSON Representation

Table 2
Performance Analysis of body temperature and heart rate

Body Temperature(ºF)	*% errorFor body temperatue*	*Heart Rate(bpm)*	*% errorFor Heart rate*
95.72	2.92	64	11.11
96.76	1.87	63	12.5
97.59	1.02	65	9.72
97.07	1.55	67	6.94
98.03	0.58	70	2.78

Table 3
Performance Analysis of blood pressure

	Blood Pressure(BP)(mmHg)		
Systolic BP(mmHg)	*% errorFor systolic BP*	*Diastolic BP(mmHg)*	*% errorFor Diastolic BP*
126	5	79	1.25
130	8.33	82	2.5
125	4.17	75	6.25
117	2.5	82	2.5
126	5	92	15

3.7. Conclusion and Future Work

In this paper, we have monitored the inpatient and outpatient vital signs. The collected data are stored in remote places and if any abnormal conditions happened, systems generate an alarm message. And then the data are transmitted wirelessly to the medical Centre via zigbee. In the medical Centre, the data are stored for further analysis and also give information about the patient status. And then the patient data are published locally using web server and the data are seen by all the doctors in the hospital.

IoT devices produce enormous amounts of data.To handle the huge data in a technological way, we have to use Internet of Things Analytics (IoTA) is implemented. Data mining, data management and data analytics techniques are used to make this data useful and medically relevant. Data processing through cloud computing and remote access to stored data improves the computing performance.

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