Design and Development of Patient Monitoring System

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Abstract. Patient monitoring system allows continuous monitoring of patient vital signs, support decision making among medical personnel and help enhance patient care. This system can consist of devices that measure, display and record human’s vital signs, including body temperature, heart rate, blood pressure and other health-related criteria. This paper proposes a system to monitor the patient’s conditions by monitoring the body temperature and pulse rate. The system consists of a pulse rate monitoring software and a wearable device that can measure a subject’s temperature and pulse rate only by using a fingertip. The device is able to record the measurement data and interface to PC via Arduino microcontroller. The recorded data can be viewed as a historical file or can be archived for further analysis. This work also describes the preliminary experimental results of the selected sensors to show the usefulness of the sensors for the proposed patient monitoring system.

1. Introduction

Nowadays, the public especially adults, would prefer not to give priority to routine health checkups mainly because they feel healthy. However, what they do not realize is that, the objective of regular medical checkups is to verify any medical problems as early as possible, so that they can avoid serious medical related troubles in the future. Furthermore, regular visits to physicians can provide them about their health current situation, which in turn, encourage them to maintain a healthy lifestyle. Another reason why the awareness of regular health checkups are low is because time constraints and transportation difficulty to visit health provider. These are also the reasons why patients with any particular illnesses who are recuperating at home have the tendency to skip regular medical check-ups at the hospital.

Therefore, in order to help the public to take care of their health within the comfort of their own home, there is the need to provide them with a portable health monitoring system which is low cost and easy to use. This work is motivated by this objective, by designing a portable patient monitoring system which can monitor body temperature and pulse rate. By using the proposed system, medical personnel can further monitor and analyze patient’s condition at his/her office without the need to meet patients.

This paper is organized as follows. Section 2 outlines the literature review related to patient monitoring system. The development of the system and experimental methods are discussed in section
3 and 4, respectively. The experimental results and discussion are described in section 5. Finally, a brief conclusion is given in section 6.

2. Literature Review

The important thing in health care is to know the conditions of the main vital signs which can be routinely monitored by health providers. Vital signs made up of body temperature, pulse rate, respiration rate (breathing rate) and blood pressure. Vital signs are useful in detecting or monitoring medical problems. Furthermore, vital signs can be monitored at health providers, at the site of a medical emergency and even at home.

There are many designs of the vital signs monitoring system in literature. Parekh has designed sensors for wearable vital signs measurement system to monitor body temperature, respiratory rate and blood pressure [1]. The work uses a thermistor as a temperature sensor, a pulse oximeter to measure blood pressure and electrocardiogram to measure heart rate. The obtained data is in real time and sent to the analog-to-digital converter (ADC) to display the output. Montgomery et al. developed a wearable physiological monitoring system for astronauts called LifeGuard which is also applicable to clinical and home-health monitoring application [2]. The device is capable of measuring ECG, temperature, heart rate, respiratory rate, oxygen saturation and blood pressure. More recently, Laine et al. developed ubiquitous healthcare systems using the Zigbee-based sensor to gather vital signs data such as ECG and heart rate [3]. The developed device is also equipped with alarms, notifications, and analysis of medical data.

There are also various vital sign monitoring devices in the market such as Welch Allyn’s Spot Vital Signs LXi and CASMED’s 740 Vital Signs Monitor [4-5]. However, these devices are very expensive and have a complex system which is difficult for home-based monitoring purposes.

3. Development of the Patient Monitoring System

Figure 1 shows the framework of the proposed patient monitoring system which will hopefully help the medical personnel on monitoring patient’s vital sign from far. The system will use an alert system via email that can save cost and time for both parties.

The system consists of a wearable device for fingertip which is connected to an Arduino UNO that processes the input from all sensors, and then, output the results using LCD display and PC. As explained in the previous section, the device is consists of a temperature sensor and pulse sensor. The user measures the body temperature by touching the temperature sensor. Figure 2 shows the DS18B20 temperature sensor utilized in this work. This sensor can measure temperatures between temperature ranges of –55[°C] to +125[°C] and is accurate to ± 0.5[°C], over the range of –10[°C] to +85[°C]. Moreover, it has a fast response time with low power consumption, making it suitable for medical applications. In the proposed monitoring system, the body temperature value is displayed on an LCD. On the other hand, a pulse sensor is used to detect the user’s pulse rate. Figure 3 shows a SN-Pulse pulse sensor utilized in this work. This sensor is a well-designed plug-and-play heart-rate sensor for Arduino UNO.

Figure 4 shows how the wearable device for fingertip is developed. As shown in the figure, the pulse sensor is attached on a Velcro strap, where the user will strap the sensor on his/her fingertip to measure pulse rate. Figure 5 shows an image of how the device is strapped on the fingertip. During this condition, the pulse rate and heartbeat waveform will be displayed on a PC monitor using Processing software.
Figure 1. Framework of the proposed patient monitoring system

Figure 2. DS18B20 Temperature Sensor

Figure 3. SN-Pulse Sensor

Figure 4. The SN-Pulse sensor attached on a Velcro strap

Figure 5. Pulse sensor strapped on the fingertip to measure heart rate.
4. Experimental Methods

In order to design an effective monitoring system, the usefulness of the temperature sensor and pulse sensor were verified through simple experiments.

*Temperature sensor test:* First, there are 3 cases for experiment using a temperature sensor:

*Case 1: cold condition* – the test subject was asked to hold an ice cube using his fingertips for 10[s] before touching the temperature sensor for 30[s], where the finger temperature was measured during this period. The result was displayed on the LCD and logged to PC.

*Case 2: normal condition* – the test subject was asked to touch the temperature sensor for 30[s] in room condition. The subject’s finger temperature was measured during this period. The result was displayed on the LCD and logged into the PC.

*Case 3: hot condition* – the test subject was asked to touch a warm water bottle using his fingertips for 15[s] before touching the temperature sensor for 30[s] before touching the temperature sensor for 30[s]. The subject’s body temperature was measured during this period. The result was displayed on the LCD and logged into the PC.

*Pulse sensor test:* In the second experiment, a user was asked to strap the pulse sensor on his fingertip as shown in Figure 5. At this moment, the user was able to verify his heart rate and heartbeat waveform on the PC monitor. Measurements were taken on two conditions, after running and at rest. In each condition, measurement was taken for 30[s].

5. Experimental Results and Discussion

Figure 6 shows the temperature sensor’s experimental setup for the temperature sensor test. Figure 6(a) shows the user touches the temperature sensor, and the LCD displays the body temperature. Figure 6(b) shows various temperature readings depending on the subject’s fingertip temperature.

As explained in the previous section, there are 3 cases of an experiment to show the usefulness of the chosen temperature sensor: cold, normal and hot conditions. Figure 7 shows the result for these 3 cases. As shown in the figure, for case 1 (cold condition), the body temperature is recorded between 20[°C] to 40[°C], compared to the case 3 (hot condition) results, where the body temperature is recorded between 100[°C] to 120[°C]. While in case 2 (normal condition), the body temperature is recorded between 60[°C] to 80[°C]. This shows that the temperature sensor can demonstrate different temperature levels clearly based on various temperature sources.

Figure 7 shows two readings of pulse rate in two conditions: after running and at rest, each condition was done for a period of 30[s]. Based on this figure, the pulse rate measurement after the
subject did a short running session shows significant higher pulse rate, where the recorded data is between 100 to 150 beats per minute (BPM). While at rest, the subject’s pulse rate is between 60 to 80 BPM. This result shows that the chosen pulse rate sensor is useful to measure the heartbeat of a person, where the pulse rate may fluctuate due to exercise activities, illness, injury, and emotions.

Finally, Figure 8 shows the pulse rate of a test subject in real-time developed using Processing software. The figure shows the pulse rate waveform and the pulse rate updated every heartbeat.

![Figure 7. Graph of temperature reading against time.](image)

![Figure 8. Graph of pulse rate reading (BPM) against time.](image)

![Figure 9. Software displaying the pulse rate of a test subject.](image)
Conclusion
In this paper, we have presented and evaluated temperature and pulse rate sensors for a low-cost vital sign monitoring system. The experimental result shows the usefulness of the selected sensors for the proposed system. Temperature sensors have been tested to measure the body temperature of a subject in 3 cases: cold, normal and hot conditions. While the pulse sensor was tested by a subject and measurements were taken on two occasions, after running and at rest. The result shows that both sensors are capable of providing sufficient data for vital signs monitoring purposes. Based on these experimental results, for the next step of development is to develop an automatic vital signs data sending capability via e-mail to make sure that the data can be sent to the health providers’ medical personnel at the comfort of the user’s home.

Table 1 shows the price list of the main hardware parts used in the proposed device. An advantage of the developed prototype is it costs less than the existing application because of the factor of hardware (sensor, etc.) used in this prototype are low-cost and affordable, but in a good quality condition.

| Types of hardware          | Price per unit (RM) |
|----------------------------|--------------------|
| DS18B20 Temperature Sensor | 17.00              |
| SN-Pulse Sensor            | 115.00             |
| Arduino UNO                | 101.76             |
| LCD Display                | 16.00              |
| **TOTAL**                  | **249.76**         |

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