Flexible Core Body Temperature Measuring Patch

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Abstract— **A rise in human body temperature can be caused by a serious illness, or an external heat flow, and may easily lead to hyperthermia, which results in weakening, nausea, dizziness, and blood pressure increase. This in an extreme situation may cause consciousness disturbances, coma or even death. Hence, abnormal temperature fluctuations need to be tracked. The sensors available in the market are inadequate for incorporation in smart textiles, because of their stiffness, complicated conversion systems and insufficient encapsulation. Hence, sensors that have high flexibility and are lightweight need to be utilized. In this paper we present the construction and implementation of flexible core body temperature patch that can be used to analyse conditions of hyperthermia and hypothermia in people using ECG sensors and a flexibly constructed temperature sensor, which can be sewn into fabric with power supplies. The core body temperature is calculated using the readings and performance is compared using the actual test results obtained**.

***Keywords**— Flexible patch, Temperature sensor, Arduino Lilypad, Core body temperature*

I. INTRODUCTION

Core Human body temperature depends upon a variety of factors including age, sex, time of the day and place in the body where it is measured. Thermoregulation in the body maintains in the range of 36.5˚C to 37.5˚C. The most commonly used methods of measuring Core body temperature are rectal, oral and tympanic which are invasive measures and cause discomfort to the patient. In this paper we have proposed a non-invasive method of measuring core body temperature. The sensors that have been used in the medical industry are predominantly inflexible and makes it difficult for people to use them at continuous and acute time intervals. The flexible medical patches available in the market are very expensive and consume a lot of time to build. Temperature is one of the major parameters that is probed by various medical practitioners to find various abnormal conditions in the human body. In all this, the core body temperature of a human can be analysed to diagnose critical health conditions like hyperthermia and hypothermia. Both invasive and noninvasive methods of measuring core body temperature are used in the ICU. The pulmonary artery catheter, which measures blood temperature, is considered the gold standard for measuring core temperatures. Core body temperature is regulated by both peripheral and central receptors that are integrated within the hypothalamus. Autonomic as well as behavioral responses to changes in temperature maintain homeostasis or a range of “normal,” around 37ºC. [1]

These sensors also have to be made flexible so that they can be used on a day-to-day basis without any hassle and to reduce the possibility of failure. Smart textiles has an increasingly growing market when it comes to flexible medical appliances as they give a cheaper alternative to the existing complicated sensors that are used. These technologies are part of the more general category of sensors in smart textile, which are materials that have been treated or modified to act as sensors, actuators and 1 or other types of transducers. By their nature, these fabrics are ideal support for sensors design that are in direct contact with people and make these easy wearable technologies be an active topic of research in various fields such as medicine, military, aerospace, including commercial because it offers technological possibilities that are not possible with conventional electronics. Based on these considerations, we took into account the design and implementation of a data acquisition system using wearable e-textile technology components. These components are in the form of reasonably sized buttons, that have an interesting aesthetic, and that can be sewn on user's clothes, making them easily accepted by them. Our idea was to fix wearable sensors network on a shirt or a cuff which can be easily attached to the hand or foot. Lilypad technology used in this data acquisition system is an e-textile technology, developed and designed by Leah Buechley and SparkFun. Each Lilypad component was creatively designed to have connectors that allow them to be sewn into clothes.

We have implemented our model using the Arduino Lilypad temperature sensors and a pulse rate monitor. The theoretical model proposed in [2] was used for the calculation of the core body temperature. The above conditions were again confirmed by using the ECG measurement that is obtained using the ECG module that is developed using the Arduino components. Finally, the setup was verified by using the actual measurements that are obtained from practical measurements.

Advantages of measuring temperature in a non-contact and non-invasive way:

- It facilitates measurement of temperature of moving targets.
- The possibility of passing contagious infections from one person to other is ruled out altogether while using non- contact thermometers. No matter how carefully you rinse or clean the bulb of the conventional mercury thermometer, the risk of infection transmission cannot be eliminated. Like while measuring temp while treating EBOLA.

- Patients need not be disturbed while using a non-invasive version. Or else they have to be woken up and the thermometer has to be kept under the tongue in a conventional system.

- There is no interference energy is lost from the target. Measurements are accurate with minimal distortion of measured values, as compared to measurements with contact thermometers.

Chapter II explains the literature survey done before implementing the project. Chapter III deals with the components used, Chapter IV deals with the design and implementation part, Chapter V elucidates the future scope of the project and Chapter VI giving the conclusion.

II. LITERAURE SURVEY

To ensure optimal performance, thermal homeostasis has to be maintained by human beings [4,5]. Heat accumulation in the body results in increase of core body temperature and thus hyperthermia. In such a state, physiological [6] as well as cognitive [7] performance may be decreased. Treatment methods can be best decided with early detection. The validity, sensor requirements, and application issues of measuring core body temperature at various sites have been reviewed previously [8,9] However, existing methods are invasive (inserting rectal or oesophageal temperature probes, etc.) and not convenient for long-term monitoring due to subject discomfort.

The experiments that have been conducted so far have measured core body temperature using invasive or contact methods which are not convenient for long time monitoring as they put the patient in a state of discomfort. To overcome this problem, we have proposed a non-invasive and a non-contact solution for measuring core body temperature which can be used for constant monitoring of a person's vitals without causing discomfort. Also, continuous evaluation of the core body temperature is possible from the values obtained.

III. COMPONENTS USED

The components that were used for making the prototype include and an Arduino Lilypad, Arduino Uno, temperature sensor, heart rate sensor, cable, USB cable, LCD, and LEDs. The tiny sized computer system in the Arduino was programmed using a programming language for easy development and modification after connecting to the computer via a USB cable.

A. Arduino Lilypad

The LilyPad Arduino USB is a flexible microcontroller board based on the ATmega32u4. It has 9 digital input/output pins (of which 4 can be used as PWM outputs and 4 as analog inputs), an 8 MHz resonator, a micro USB connection, a JST connector for a 3.7V LiPo battery, and a reset button. It differs from previous LilyPad boards in that the ATmega32u4 has built-in USB communication, eliminating the need for a separate USB-to-serial adapter. It can be sewn to fabric and to power supplies, sensors and actuators with conductive thread.

B. MCP9700 – Temperature sensor

The MCP9700 shown in Fig. 1 is a small, low-cost, low-power sensor with Linear Active Thermistor Integrated Circuit (IC). Unlike resistive sensors, e.g., thermistors, the Linear Active Thermistor IC does not require an additional signal-conditioning circuit. The biasing circuit development overhead for thermistor solutions can be avoided by implementing this low-cost device. The Voltage Output pin (VOUT) can be directly connected to the ADC input of a microcontroller. In addition, this family is immune to the effects of parasitic capacitance and can drive large capacitive loads.

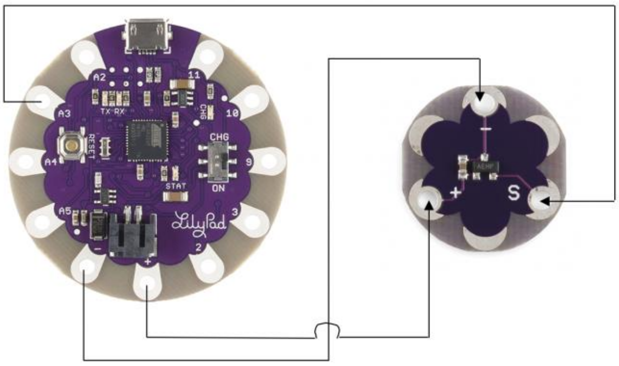

Fig. 1. MCP9700 temperature sensor setup

C. Pulse sensor

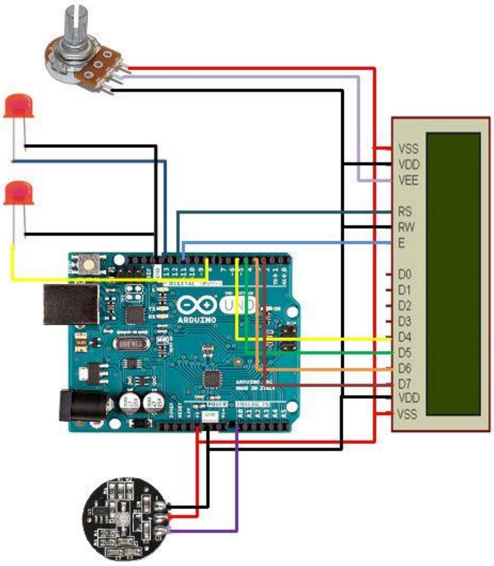

Fig. 2. Pulse rate sensor setup

The Pulse Sensor shown in Fig. 2 is a plug-and-play heart-rate sensor for Arduino. It essentially combines a simple optical heart rate sensor with amplification and noise cancellation circuitry making it fast and easy to get reliable pulse readings. There is also a LED in the centre of this sensor module which helps in detecting the heartbeat. Below the LED, there is a noise elimination circuitry which is supposed to keep away the noise from affecting the readings.

The pulse sensor module uses reflected light for measuring the pulse rate. When in contact with one's finger, the reflected light will change based on the volume of blood inside the capillary blood vessels. During a heartbeat, the volume inside the capillary blood vessels will be high. This affects the reflection of light and the light reflected at the time of a heartbeat will be less compared to that of the time during which there is no heartbeat (during the period of time when there is no heartbeat or the time period in between heartbeats, the volume inside the capillary vessels will be lesser. This will lead higher reflection of light). This variation in light transmission and reflection can be obtained as a pulse from the output of pulse sensor. This pulse can be then conditioned to measure heartbeat and then programmed accordingly to read as heartbeat count.

IV. DESIGN AND IMPLEMENTATION

The parameters required to predict the core body temperature are body surface temperature and the heart rate. We have used flexible components that can be sewed into fabric for the safety and comfort of the patient while enabling constant monitoring. For measuring the surface body temperature, the Lilypad Arduino has been sewed with the corresponding temperature sensor into a shirt for monitoring the surface body temperature. The temperature sensor was placed near the armpit and calibrated using temperature readings obtained from a thermometer placed in the same spot for accuracy in measurement.

To measure the heart rate we used the Pulse sensor, which was connected to the Arduino Uno. This sensor is light weight and can be easily sewn into fabric. A LCD screen was also included in the circuit to view the pulse rate. The Pulse sensor is positioned in the fingertip and the output is given in beats per minute (bpm).

The prototype of these two sensors has been done separately but, they can be integrated and sewed together with the Lilypad Arduino to further simplify the design.

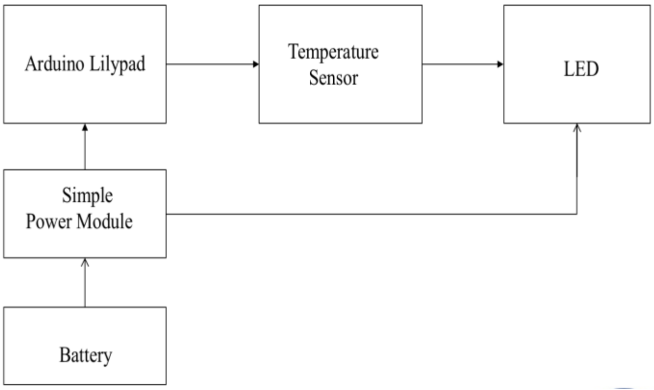

Fig. 3. Block Diagram - Temperature sensor

The implementation of the flexible non-contact and non-invasive temperature sensor and the heart rate sensor have been shown in the figures below. The vales obtained from the sensors is used to calculate the core body temperature.

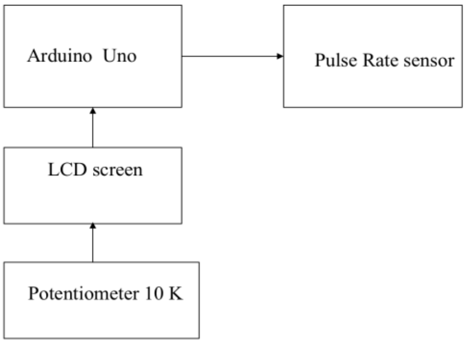

Fig. 4. Block Diagram - Pulse Rate Sensor

The physical measurements of temperature and heart rate will be utilized to estimate the core body temperature. The formula is as follows:

$$Tre = 15.35 + (0.648*Tis) + (0.008*HR) - (0.381xWork) \quad (1)$$

The reference for the core body temperature can be found in [3]. Fig. 3 and Fig. 4 represent the block diagrams. Fig. 5 shows the prototype of the temperature sensor and Fig. 6 shows the prototype of the pulse sensor.

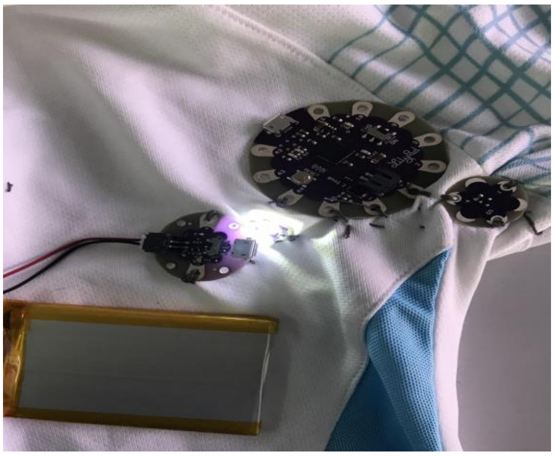

Fig. 5. Prototype of Flexible temperature sensor

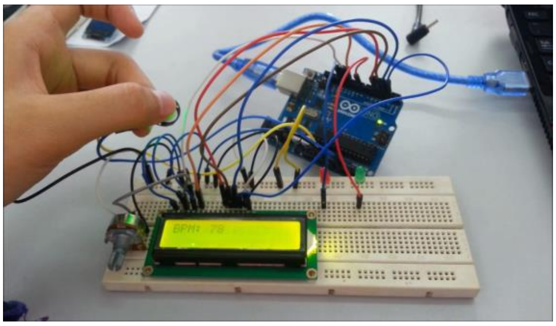

Fig. 6. Prototype of Pulse sensor

V. RESULTS AND EVALUATION

The formula in [3] was used to get the results that were studied in comparison with actual core body temperature readings. We found that the measured core body temperature readings were almost similar to the actual readings as shown in the bar graph in Fig. 7. The skin temperature was also obtained by using the temperature sensor setup and recorded for a comparison of the core body temperature and skin temperature. The results of which are also shown in Fig.7. We can also note that there is a marked variation between the skin temperature and the core body temperature as can be observed from the graph.

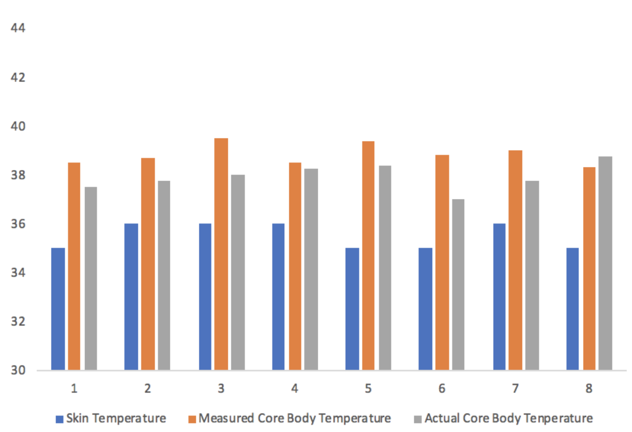

Fig. 7. Comparison between Skin, Measured and Actual Core Body Temperature

We have also used an ECG module that will be able to crosscheck the results that were obtained using the prediction setup. It can be found in [14] that abnormal conditions of core body temperature can be corelated with the ECG. So we have also instilled the ECG module that will improve the predictions and verify conditions of hypothermia and hyperthermia.

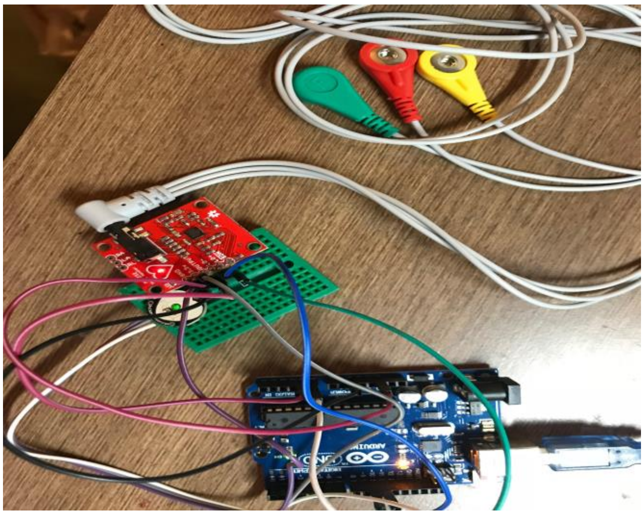

Fig. 8. ECG setup along and the pulse sensor

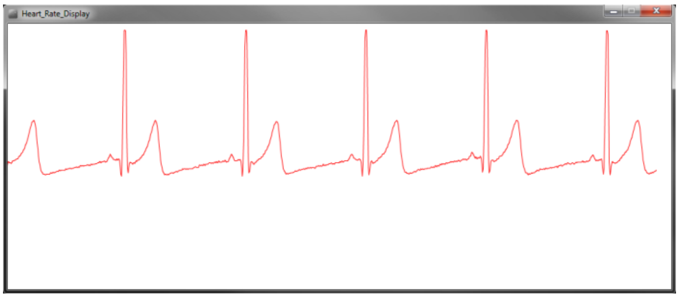

Fig. 9. ECG measurement in a normal condition

VI. CONCLUSION

In this paper, we have studied the implementation of a flexible core-body temperature measuring patch. This is a prototype and there can be improvements made to increase the accuracy of the system. The ECG module has been implemented separately, but in a future version that can be integrated along with the temperature patch to improve convenience.

VII. REFERENCES

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