Personalized Temperature Control System for Hypo and Hyper-thermic Patients

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Abstract

In the medical field, every health problem is defined by its own symptoms. Certain infections (bacterial or viral infections), endocrine disorders (thyroid or adrenal disorders), heart disease or heat-related disorders (heart stroke or heat exhaustion) can cause hyper-thermic condition, which confuses, agitates, and increase the person's anxiety level [1]. An underactive thyroid function, a malnutrition, tachycardia or even neurological disorders can contribute to recurrent hypothermia which, in its turn, is related to an abnormal body temperature causing a high lack of coordination and confusion for the diagnosed person [2].

The proposed system acts like a temperature control device. Using a temperature sensor and heartrate sensor, it is able to capture any abnormalities in the individual's body temperature and heartrate respectively. The main component is the Peltier element used for the achievement of a cooling process in case of hyperthermia or a heating process in case of hypothermia in order to decrease in a quick and effective way the side effects of the thermal irregularities on the person's body.

All these processes will be controlled by the user via a mobile application letting him activate his desired medical mode. As well as an automatic system activation in case of severe thermal shocks. It is a low cost, efficient and convenient product.

Keywords: hyperthermia, hypothermia, mobile application, temperature, heartrate.

Introduction

Physiological signal monitoring is crucial for determining the state of the body, especially when it comes to controlling body temperature. Wearables have grown in popularity for this reason as analog and digital integrated circuit technology has advanced. Experts in the medical profession stress the significance of keeping an eye on vital signs, particularly for people who are at danger, like those who have hypo- or hyperthermia disorders.

Objectives

The goal of this project is to create a wearable clothing device with monitoring and temperature control capabilities. The clothing's embedded sensors for temperature and heart rate monitoring will take part in activating the device when it is worn. A smartphone app is used to control the system that uses a Peltier module to produce heating or cooling as needed.

Literature review

In order to find solutions regarding the hyperthermia and hypothermia conditions, several studies are being carried out. For the purpose of investigation concerning the effects of moderate hypothermia on human performance, specifically with regard to cognitive and motor functions, researchers recruited healthy individuals who engaged in cold-water exercise to reduce their body temperatures. The participants specifically engaged in variable-speed treadmill walking while submerged to the waist or chest in either 10°C or 15°C water until a core temperature of 35.5°C was attained [3]. After that, they conducted a number of medical and mental examinations. Their test results were contrasted with their results in the absence of hypothermia. Physical testing was done on both the upper and lower bodies to ascertain the effects of local tissue cooling [3]. In another study, several individuals in their twenties developed hyperthermia as a result of increased outside temperatures and physical exercise [4]. A variety of probes were used to measure their body temperatures. They were submerged in cold water baths of varying temperatures until the extra heat from the exercise was removed once their temperatures had reached a certain point. Depending on the temperature of the water, different amounts of time were needed to remove this heat. There were no negative effects noted, and the subjects didn't express any severe discomfort [4]. Therefore, multiple researchers worked on the idea of finding solutions that helps with treating or even bypassing the painful and exasperating side effects of hyperthermia and hypothermia starting with researches and experiments on healthy individuals and moving to human beings with unstable health states.

Researchers from Tokyo tech unveiled a similar system that regulates clothing temperature but it lacks many fundamental features. Henceforth the absence of a heart rate sensor as well as a continuous heart rate and temperature monitoring via the mobile application, the reminder message and the system’s automatic activation whenever abnormalities occur that can both participate in saving many lives.

Methodology

The Personalized Temperature Control system contains an embedded network of various sensors and modules working together in order to give good accuracy and protection. The main components of this device are the temperature sensor, the heart-rate sensor and the Peltier element.

Once the device is connected to the batteries and is turned on, both implemented sensors are going to detect the body temperature and the heart rate level respectively with a continuous data recording. The recorded values will be sent to a mobile application. Specific heart-rate and temperature values will be associated in this system in order to grant the system the power of differentiating between hyper-thermic and hypothermic conditions. Thence, the Peltier module is responsible for converting from cooling to heating application and vice versa, in the purpose of either warming (in case of hypothermia) or cooling (in case of hyperthermia) the body. This resourceful innovation has a lot of potential usage in comfort technology and healthcare. Moreover, this circuitry will be wirelessly controlled via a mobile application allowing the user to choose his desired option in case he feels the beginning of his thermal shock, which can be quickly done due to the presence of different buttons in this mobile application linked to turning on cooling or heating processes. Thus, in emergencies, a reminder SMS will be sent

via the application to the individual's smartphone alerting him about the need of turning on the Peltier element. If no interaction was done, an automatic system activation is available which is relying on the sensors output values, so in the case of long-lasting abnormalities with no intervention from the individual in turning on the system from his phone, the Peltier module is programmed to choose the right process for the corresponding vital signs.

Figure 1 shows the interrelationship among these modules and the flow diagram emphasizes the processes of the system is described in figure 2.

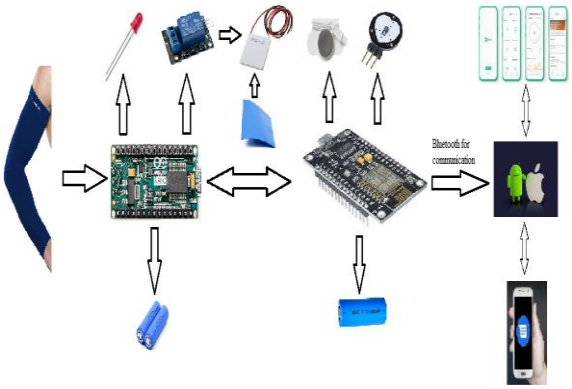

Figure 1: Design of the system

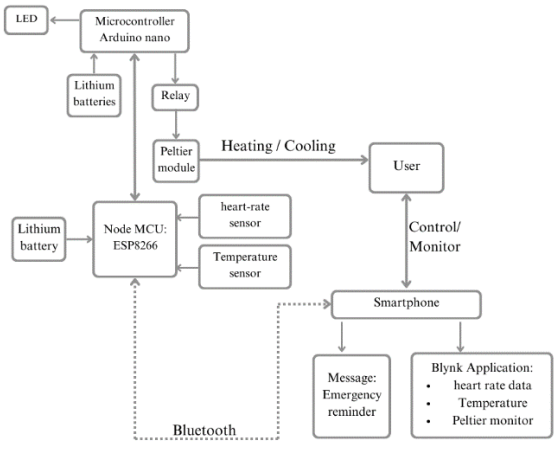

Figure 2: Block diagram of the system

Temperature sensor

This skin surface temperature sensor is intended to provide precise measurements and can be applied to any portion of the body. As shown in figure 3, it has a soft sticky foam disc for simple installation and removal, and the Mylar backing protects the sensor from heat lamps and other sources of light, improving accuracy. The lead wire is thinner and more flexible, which reduces ambient air interference (the stem effect). The sensor is integrated in the foam disk's center to reduce the possibility of separation and discomfort, especially for people with thin or sensitive skin. The main use of this temperature sensor is to capture the individual's body temperature and compare it to predefined values in the microcontroller memory [5].

Figure 3: Medline skin temperature sensor [5]

Heart rate sensor

The heart-rate sensor (figure 4) determines the electrical activity of the heart represented by beat-per-minute. This component will participate with the temperature sensor in identifying whether the person is facing the hyperthermia or hypothermia conditions or not. Scientifically proved, the hyperthermia condition will cause the increment of heart rate ~10 beat-per-minute [6], while, the hypothermia state will lead to a decrement of the individual's heart rate down to 10 beat-per-minute and cardiac output drops ~7% per °C [7].

Figure 4: Heart Beat Rate Amped Sensor [8]

Peltier electric cooling device

The Peltier module (figure 5) is a thermal control module that provides the cooling and warming effects. When an electrical current passes in the device, “Peltier effect” is created and is defined by the movement of electrons and positive holes in 2 different elements of the module creating 2 different sides: hot and cold. It can be switched depending on the current direction and on the desired therapeutic treatment, either the need for a cooling process in case of hyperthermia or a heating treatment in the event of hypothermia [9].

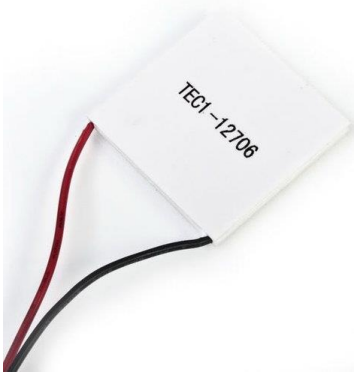

Figure 5: TEC1-12706 Peltier module [10]

Arduino NANO

The Arduino Nano is a microcontroller-based device with 16 digital pins used for various purposes (figure 6). It can be used for almost every task, from minor to massive industrial-scale projects. It can also be used for prototyping and developing new applications. This component is considered as the main brain of our device as well as its responsibility in monitoring and comparing the different values captured by the remaining components [11].

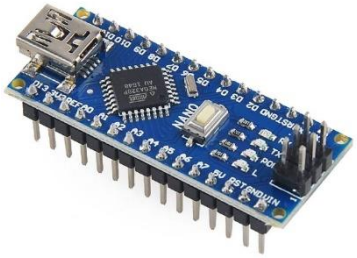

Figure 6: Arduino NANO module [11]

Arm-band sleeve

A simple arm-band sleeve without compression enclosing all device’s circuitry required for both types of treatment represented in (figure 7).

Figure 7: Arm-band sleeve [12]

Thermal pads

Considered as an excellent thermal conductor with defined insulation properties and known as “heat resistant silicone thermal pads” [13], two of these sheets (figure 8) are used in order to shield the Peltier element from direct contact with human skin while maintaining efficient heat and cold transfers.

Figure 8: Thermal pad [13]

GSM module for SMS:

The GSM module (figure 9) embedded in this device will send an SMS reminder to the SIM of the same person wearing this temperature control system whenever a hyperthermia/hypothermia begins in order to remind the user about turning on the cooling/heating system.

Figure 9: SIM900 GSM module [14]

Mobile application

The ESP8266 12-E NodeMCU (figure 10) is a Wi-Fi module that is used in the development of Internet of Things (IoT) devices. It is based on the ESP8266 system-on-chip which integrates a microcontroller unit and a Wi-Fi radio. Using this unit allows interfacing with external sensors, actuators, and other devices.

Figure 10: The ESP8266 12-E NodeMCU module [15]

Once all signals are met, recorded data can be sent to a mobile application. With the help of MIT application inventor (provided by google) a software application for android system was developed and all sensors' data were saved and monitored via an android device in addition to turning on and off the Peltier module when needed.

Conclusion

The personalized temperature control system is a gadget that has the potential to help every individual suffering from the physical and mental difficulties caused by hyperthermia and hypothermia conditions stop by vanishing side effects by the virtue of controlling the whole system using a mobile application allowing the user to choose his desired medical procedure. Providentially, this device will be turned on automatically in case of intervention's absence from the individual himself, keeping hyperthermia and hypothermia consequences away from the user's body. As a future work, a collaboration with Germany will be held in the aim of adding a safety chip ensuring the safe conduct of operations minimizing the risk of accidents and preventing personal and environmental harm.

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