IoT Based Brain Hypothermia Monitoring and Controlling Management System

Khaled A. Hassan[1], Asst. Prof.Hadeel N. Abdullah[2],Asst. Prof.Salwa A. Abd-AlHameed[3]

[1]Electrical Engineering Department, University of Technology Baghdad-Iraq.
310319@student.uotechnology.edu.iq
[2]Electrical Engineering Department, University of Technology Baghdad-Iraq.
30002@uotechnology.edu.iq
[3]Electrical Engineering Department, University of Technology Baghdad-Iraq.
Article Received: 28 May, 2021; Article Revised: 31 May 2021; Article Accepted: 2 June 2021

Abstract: In this work, a non-invasive, selective brain cooling device is designed and manufactured. Thermoelectric cooling elements were used and fitted inside the proposed helmet as cooling means for the head. The thermoelectric was cooled using water circulation to make the proposed system provide a long operational time and maintain the system's cooling rate. NTC temperature sensors are used to collect a patient's temperature at four locations; inside the ears and on artery temporal. By utilizing four sensors for temperature measurement, any error that can occur will have less impact on the whole system's intended performance. Arduino microcontroller and Raspberry Pi are used for data processing and visualization. The Raspberry Pi is used to create a server running Node-Red software, where the data will be published to the local Wi-Fi network and the internet using MQTT protocol. The proposed ABHS achieved two main points; first, the developed helmet is flexible and weight about 1.2 Kg, which make it suitable for all ages, second the designed water-cooling system kept the system cooling rate at maximum throughout the time required for the system to operate which is between 24 to 72 hours.

Keywords: Hypothermia, Brain temperature, Microcontroller, Peltier, NTC, Node-Red software.

1. Introduction

Internet of Things ensures that things connect with the internet using sensors, microcontrollers, and transceivers to empower connectivity and be developed with sufficient Protocol stacks that help them communicate with each other, connect with customers, and become the constituent part of the internet. Today, the Internet is Effect on many facets of the daily life of the potential client It's survival. By holding this stuff in mind, there are many applications Built based on IoT, in which any physical object is placed—linked to the internet by the use of sensor devices. This is the Healthcare reliance on IoT growing regularly. Improve access to services, enhance the quality of treatment, and reduce treatment costs (Kodali, 2015). This means that the IoT lends itself as an ideal method for controlling health care activities. Remote control of conditions impacting works tends to maintain and promote their integrity in the long run. IoT is one of the key tools used in today's technologies to help track activities. IoT has become an important technique and can be found in objects, small built-in devices that provide computation, networking, and sensing (Radharamana, 2019). Physicians with IOT can calculate vital signs and other biometrical details for patients with attached sensors. So, the illnesses and problems may be easily monitored. With the aid of IoT hospitals and emergency services, they will easily be alerted when patients require their services. IOT roads and traffic signs can be managed to help ambulances access the hospital quickly (Khatoon, 2020).

In general, the brain temperature is greater than body temperature however corresponds entirely with body temperature. Varying in both pathological and physiological unhealthy situations, brain temperature itself mostly relies on the summed influences of these principal variables: Cerebral blood flow (CBF), volume brain metabolism, and blood temperature. Temperature variations of 1◦C or less could lead to functional alterations in several regions of the nervous system (Shefchyk,1984). TH(TH) is characterized as lower core body temperature from 32°C to 3althoughno permission exists about the precise cooling level. Specialists prefer these descriptions (Rivera-Lara, 2012):

New paragraph: use this style for beginning a new paragraph.

- Mild hypothermia (34 → 35.9°C)
- Moderate hypothermia (32 →33.9°C)
- Moderate deep hypothermia (30 → 31.9°C)
- Deep hypothermia (<30°C)

The main input of engineering for therapeutic brain hypothermia is to design safe and dependable devices to attain target temperatures and cooling rates. New technologies are usually assessed for safety and thermal efficacy in large and small animal models to determine their trials' fitness. During the design, patient safety is prime, including physical trauma, induced freezing damage to tissue, leakage of coolant, etc. Serializability, reduce the size with thermal performance needs, and physical dimensions are distinctive design considerations at device development.

Brain cooling techniques comprise blood, intravascular, and surface cooling. Nevertheless, defining the suitable temperature is challenging due to notable variations amongst individuals and variations over time in patients.The main features of this paper is to present a hypothermia monitoring and control system that utilizes an IoT platform via sending the data from raspberry pi to a virtual computer by MQTT and enable the doctors to access these data via an HTTP web page.

2. Introduction

Valsalan and et.Al,(Valsalan, 2020) proposed a continuous monitoring and control instrument to screen the patient's status and store the patient's details in a server using Wi-Fi Module-based remote communication A remote health management device based on IoT is proposed, through which allowed individuals may access data stored on any IoT platform. Doctors at a distance detect illnesses based on the beliefs they obtain. Hadis and et. al,(Hadis,2020)developed a device for measuring a patient's two main vital signs, body temperature and respiratory rate The monitoring device was built on an IoT framework with an Arduino Mega 2560 and an ESP8266 Wi-Fi Module. Nurses will track the patient's status using this method by installing android applications on any Android smartphone. Nurses and doctors may now check past vital sign statuses by importing cloud data in excel format. When the two vital sign levels derived from this instrument were compared with normal measuring instruments or manual observation, the findings were almost identical. Sahaand et.al,(Saha, 2021)proposed a prototype system for a real-time health monitoring system using the a DS18B20 temperature sensor, Arduino Nano with microcontroller ATmega328, where the ZigBee module is used for wireless communication. The sensor vitals are collected and sent to the computing device using shielded cable and ZigBee, through wired and wireless communication, respectively. Analysis of patient vitals based on medical definitions gives the patient’s real-time health condition so that if the condition is not normal, then timely preventive measures can be taken to avoid further complications. Bashir and et. al,(Bashir, 2020) proposed a low-cost internet of things (IoT) enabled COVID-19 standard operating procedure (SOP) enforcement device that counts the amount of people entering and exiting a vicinity, maintains physical separation, controls body temperature, and alerts attendees and managers to breaches. The device is made up of several sensor nodes that communicate with a centralized server. The server's details will be used for regulatory auditing, real-time reporting, and preparation. The framework would not keep track of attendees' personal details or have contact information. Islam and et. al,(Islam, 2020) proposed a smart healthcare device in an IoT environment that can track a patient's essential health signs as well as the room state in which the patient is currently in real-time Five sensors are used in this device to collect data from the heartbeat sensor, body temperature sensor, room temperature sensor, CO sensor, and CO2 sensor. The established scheme's error percentage is below a certain limit (5%) for each scenario. The built prototype is well adapted for healthcare surveillance, as shown by the system's efficacy. Leeand et. al, (Lee, 2019) Built device consists of hardware such as microcontrollers such as Arduino, personal computers (for display), sensors (for measuring body temperature), buzzers (for alarm), and Arduino program (version1.7.10). The Arduino is quick to use and easy to communicate with a sensor. Essentially, the system is programmed to continually regulate the skin temperature to signal the onset of hyperthermia. The proposed model framework offers an integrated user interface that is simple and accurate to monitor body temperature and buzzer sound warning in the event of hyperthermia. It thus provides a more reasonable measure of temperature rise. The temperature state obtained will be transmitted via Arduino to the monitor window. Analyzing body temperature would be useful for bedridden patients and athletes in hospitals. The final model will boost users' ability to observe their body temperature consistently and identify hyperthermia at its initial level. Cojocaru, and et. al, (Cojocaru, 2018) described an improved form of non-invasive hypothermia for brain cooling used in stroke therapy. The originality is the extra powerful cooling system used on the scalp. Its practice tends to stabilize the condition of the patient and prevent the problems of the state. Patients with brain surgery should use this system. It cannot be used by any patient, though, since some chronically ill patients die and, in this case, symptoms stay on their scalp. Tauchi, and et. al, (Tauchi, 2018) Described on the focal cerebral cooling system for animals and its focal cooling performance in some animal models of ischaemic cerebral stroke A focal cerebral cooling device was built using the Peltier portion, a thermoelectric heat pump. The device was validated for its cooling capacity and optimal settings to induce efficient intracranial temperature. Gupta and et. al, (Gupta, 2020) presented the operation of the Peltier module based on an air-conditioned helmet. The benefit of this helmet is that it delivers an easy ride during hot summers, and the best aspect is that it operates on free energy that is wind. Therefore, it improves the helmet's usage and decreases the injury rate. Experimental testing is carried out, and findings are provided to show the suggested solution's viability in experimental work. A test model is developed to validate the prototype.

3. The Proposed Work

The proposed system consists of several components with Arduino as the main part, which controls the whole system's electrical operations. While raspberry pi is employed to visualize the patient collected data on a screen and establish communication with the online server via MQTT. Arduino Mega serially sends the data to Raspberry Pi, which is the same USB cable that connects Arduino and Raspberry Pi used to power up the Arduino board. The data send in an array format.

Any USB port on the Raspberry Pi can be utilized to receive the data. The serial connection simplifies the work process of receiving the data on the Raspberry side of the circuit.

The patient's collected data is the head's temperature at four locations using 10K Negative Temperature Coefficient (NTC) temperature sensors. Figure (1) shows the location of these sensors. Peltier elements as the cooling mean for the system. The online server consists of a virtual computer with an Ubuntu Linux operating system installed on it. On both the local raspberry pi and the virtual computer, Node-red software was installed. The Node-red software allows for easy visualization of the collected temperature data and transmitting them to the online server via MQTT protocol. Figure (2) present the block diagram of the proposed system.

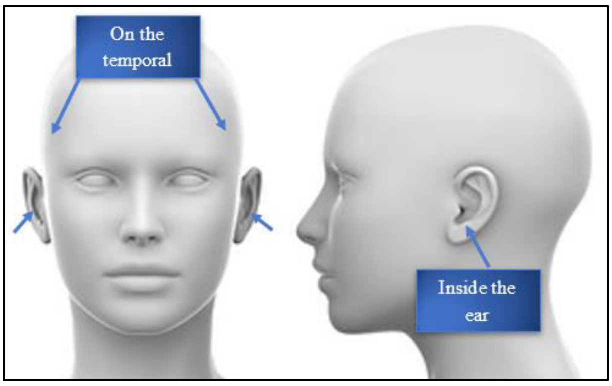

Figure 1. Shows the location of these sensors

The accuracy of the temperature reading depends on knows the precise value of NTC resistance and match it with the exact value for the knows resistor to create the voltage divider, so a variable resistor of 20K has been used to adjust its value to the desired resistance using a multi-meter.

To operate the device, they need to set the desired level of temperature. A four-by-four keypad is used to initiate the function in charge of setting the temperature. The hash button is pressed, followed by the temperature value. The 16-button keypad provides a user interface component for the microcontroller, where the operator can key in the temperature set point easily. Based on the patient temperature and the set temperature Arduino control the cooling elements ON/OFF Peltier. Figure (3) shows the flow chart of the ABHT program.

For Node-red software, an identical interface has been created for the raspberry pie and the online server to make it easy and familiar for the medical staff to read the data. Figure (4) present the developed dashboard for the proposed system.

Node-RED's library includes about 3.000 flows and nodes. A node implementation could be seen as an adapter of a service or device that makes the functionality obtainable. Using Node-RED's GUI, nodes could be attached to create flows. A flow could as well comprise sub-flows.

Figure (5) and Figure (6) show the proposed system hardware implementation and the developed helmet. The helmet is made from leather which makes it easy to fit on almost any head size. The weight of the developed helmet is about 1.2 Kg. Water cooling is considered to remove heat from Peltier's hot side.

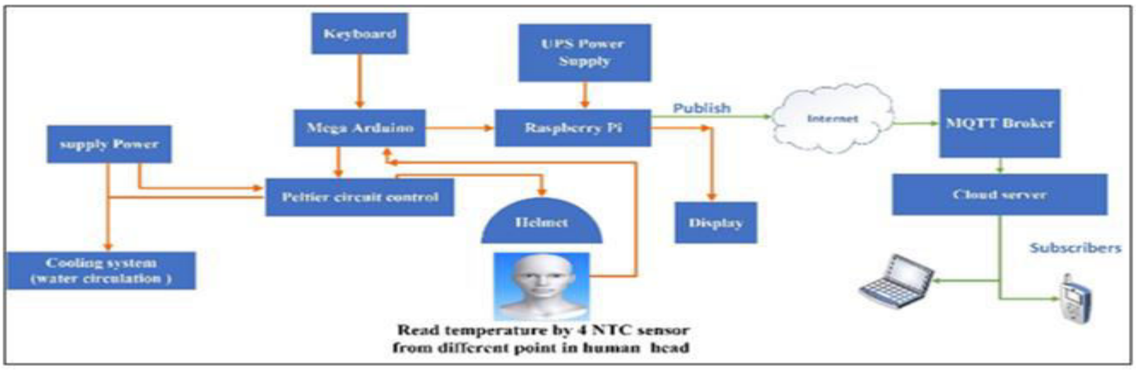

Figure 2. Block Diagram of the Proposed System.

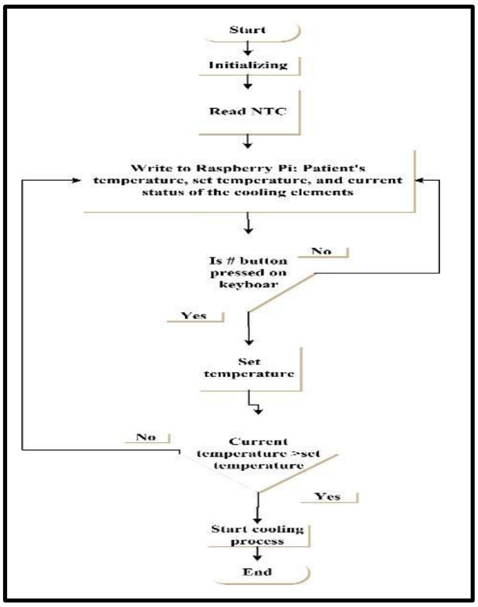

Figure 3. ABHT Program Flow Chart

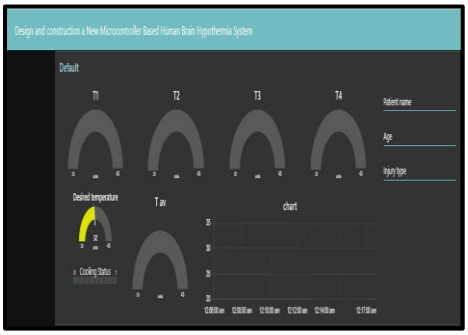

Figure 4. Final GUI for The Proposed system

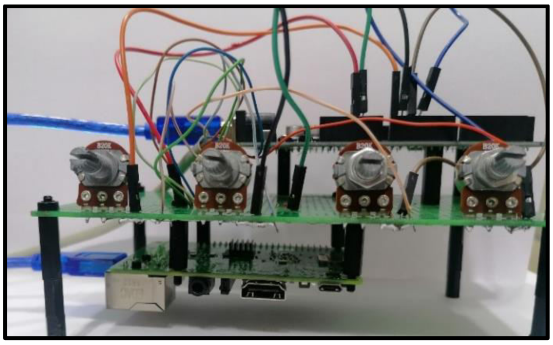

Figure 5. Control and vitalization circuit

(a) (b)(c)

Figure 6. Cooling Helmet

3.1 MQTT

MQTT is a publish-subscribe protocol that works on TCP/IP protocol suite. It is a lightweight protocol intended to maximize network traffic. MQTT could be utilized for mobile applications and also for sensor machines and telemetry applications. The public subscribe messaging needs a message broker. Therefore, the MQTT broker performs as an intermediate to forward the publishers' received message to the subscribers (Rattanapoka, 2019). Figure (7) present the general structure of the MQTT protocol.

In this work, the MQTT protocol is utilized to send data from the on-premises Raspberry Pie via the internet to a cloud-based server that will make subscribers to the local Raspberry Pie. The cloud-based server runs Linux as an operating system where a virtual machine is set up to run Node-red software. The allowed users can access the online server's website to monitor the patient's status under monitoring via any commercial web browser by entering the link for the server. The data in the web browser will be presented in real-time.

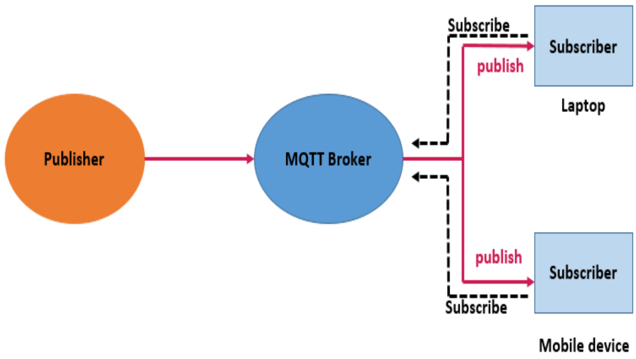

Figure 7. MQTT working

3.2 Node.js

Based on nodejs.org, "Node.js is a JavaScript runtime. Node.js utilizes a non-blocking, event-driven I/O model that makes it efficient as well as lightweight. NPM is the largest open-source libraries ecosystem in the world". Node.js has played an essential role in web-based application growth. Node.js aids the developer control both back, and front ends with JavaScript, with fewer resources and time required.

3.3 Wi-Fi

It is a network technology, gives IEEE 802.11 standard. Since the vast majority of electronic devices, these days can transmit the wireless signal. A router permits different devices to have internet. Since Raspberry Pi supports a Wi-Fi connection, the establishment cycle doesn't need wiring and can be extended without any problem. The vast majority of tablets, cell phones, and PCs are Wi-Fi enabled so clients could get to the system without trouble and additional equipment.

Node-RED could be arranged to take into account network, security, and so on. By default, the Node-RED editor is not protected; anybody can access its IP address could access the editor and deploy changes. The Admin API and Editor support two authentication types: property in the settings file.

4. Results and discussions

The proposed system graphical user interface can be seen in Figure (8), where the system is measuring the temperature for the four sensors and the average temperature is taken for the four sensors; the average temperature is the one that the system will consider to react on to turn ON/OFF the cooling elements. The developed helmet has weights of 1.275 Kg, which is very lightweight and free size. It is designed to cover the whole skull. The weight and the helmet's flexibility make it unique compared to other helmets where the weight is more than 5 kg and not flexible (Cojocaru, 2018). The data transmission from the raspberry pi to the online server was steady at fifteen seconds per MQTT transmission, which allowed for almost real-time monitoring of the patient's head temperature. Simultaneously, the control of the cooling elements was done locally to make it very precise, as it is most crucial to have real-time controlling the cooling system. The online server's link was protected by the built-in Node-red password protection, which allowed only authorized persons to access the specific patient data. The final developed prototype is shown in Figure (9).

Figure 8. ABHS during operation

Conclusion

Hypothermia treatment proved to be very effective in reducing the damage and prevent future harm to the brain cells. Making the monitoring system online and easy to access by the doctors allowed the doctors' treatment easier. It managed several cases simultaneously since the doctors did not need to be presented at the patient's rooms. Using MQTT as the transfer protocol from the local raspberry pi to the online server was an easily managed IoT device protocol. While to reduce the risk of hacking, HTTP protocol was used to allow online access for the patient data without exposing the main monitoring device to the public. The cost and maintenance of the system can easily be done as all the parts are available locally.

Figure 9. ABHS device.

References

Bashir, A., Izhar, U., & Jones, C. (2020). IoT based COVID-19 SOP compliance monitoring and assisting system for businesses and public offices

Cojocaru, V., Fedorisin, T., Niguleanu, E., & Galus, R. (2018, June). Intelligent device for controlled therapeutic hypothermia. In *2018 10th International Conference on Electronics, Computers and Artificial Intelligence (ECAI)* (pp. 1-6). IEEE.

Gupta, N., Kumar, V., Dhasmana, H., Verma, A., Kumar, A., Shukla, P., ... & Jain, V. K. (2020). Improving Thermal Comfort in Helmet Using Phase Change Nanocomposite Material. In *Advances in Solar Power Generation and Energy Harvesting* (pp. 45-52). Springer, Singapore.

Hadis, N. S. M., Amirnazarullah, M. N., Jafri, M. M., & Abdullah, S. (2020, May). IoT Based Patient Monitoring System using Sensors to Detect, Analyse and Monitor Two Primary Vital Signs. In *Journal of Physics: Conference Series* (Vol. 1535, No. 1, p. 012004). IOP Publishing

Islam, M. M., Rahaman, A., & Islam, M. R. (2020). Development of smart healthcare monitoring system in IoT environment. *SN computer science*, *1*, 1-11.

Khatoon, N., Roy, S., & Pranav, P. (2020). A survey on Applications of Internet of Things in Healthcare. In *Internet of Things and Big Data Applications* (pp. 89-106). Springer, Cham.

Kodali, R. K., Swamy, G., & Lakshmi, B. (2015, December). An implementation of IoT for healthcare. In *2015 IEEE Recent Advances in Intelligent Computational Systems (RAICS)* (pp. 411-416). IEEE.

Lee, J., Cho, H. R., Cha, G. D., Seo, H., Lee, S., Park, C. K., ... & Kim, D. H. (2019). Flexible, sticky, and biodegradable wireless device for drug delivery to brain tumors. *Nature communications*, *10*(1), 1-9.

Radharamana, K., Mouli, C., & Kumar, U. (2019). Web Architecture for Monitoring Field using Representational State Transfer Methods. *Int. J. Intell. Eng. Syst*, *12*, 84-93.

Rattanapoka, C., Chanthakit, S., Chimchai, A., & Sookkeaw, A. (2019, December). An MQTT-based IoT cloud platform with flow design by Node-RED. In *2019 Research, Invention, and Innovation Congress (RI2C)* (pp. 1-6). IEEE.

Rivera-Lara, L., Zhang, J., & Muehlschlegel, S. (2012). Therapeutic hypothermia for acute neurological injuries. *Neurotherapeutics*, *9*(1), 73-86.

Saha, R., Biswas, S., Sarmah, S., Karmakar, S., & Das, P. (2021). A Working Prototype Using DS18B20 Temperature Sensor and Arduino for Health Monitoring. *SN Computer Science*, *2*(1), 1-21.

Shefchyk, S. J., Jell, R. M., & Jordan, L. M. (1984). Reversible cooling of the brainstem reveals areas required for mesencephalic locomotor region evoked treadmill locomotion. *Experimental brain research*, *56*(2), 257-262.

Tauchi, M., Tejada de Rink, M. M., Fujioka, H., Okayama, S., Nakamura, K. I., Dietel, B., ... & Harada, H. (2018). Targeted temperature management: peltier's element-based focal brain cooling protects penumbra neurons from progressive damage in experimental cerebral ischemia. *Therapeutic hypothermia and temperature management*, *8*(4), 225-233.

Valsalan, P., Baomar, T. A. B., & Baabood, A. H. O. (2020). IoT based health monitoring system. *Journal of Critical Reviews*, *7*(4), 739-743.