THE ANNALS OF “DUNAREA DE JOS” UNIVERSITY OF GALATI
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N°. 3 - 2024, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2024.3.03

AN INTELLIGENT SYSTEM FOR TEMPERATURE BODY MONITORING USING ARDUINO PLATFORM

Mihaela MARIN[1,2], Alexandra BORŞAN[1], Laura-Daniela BURUIANĂ[1,2], Florin-Bogdan MARIN[1,2]
[1] “Dunarea de Jos” University of Galati, Romania
[2] Interdisciplinary Research Centre in the Field of Eco-Nano Technology and Advanced Materials CC-ITI, Faculty of Engineering, “Dunarea de Jos” University of Galati, Romania
e-mail: florin.marin@ugal.ro

ABSTRACT

An accurate measurement of the body temperature is a critical component in monitoring the human health, with applications ranging from clinical diagnostics to wearable health monitoring systems. Using the Arduino platform for body temperature monitoring provides an affordable, customizable and efficient solution for a wide range of applications, from personal care to patient monitoring in hospitals, this type of device can significantly contribute to improving health and safety. The MLX90614 sensor is an innovative and efficient solution for temperature measurement in the medical engineering field. With its outstanding accuracy and adaptability in measuring body temperature and medical devices, this device asserts itself as an indispensable tool in monitoring and managing the health of patients and medical devices in a variety of clinical and treatment settings.

KEYWORDS: body temperature, monitoring system, MLX90614 sensor, Arduino

1. Introduction

The body temperature is an indicator of health. Both high and low ambient temperatures are heat stressors that, like other physiological responses, induce activation of the hypothalamic-pituitary-adrenal (HPA) axis and secretion of arginine-vasopressin (AVP) or antidiuretic hormone. This hormone has an important role in controlling fluid balance and a role in blood pressure regulation through its vasoconstrictor effects on blood vessels [1-3].

Body temperature is universally considered a constant, approximately 37 °C. However, this can vary depending on age, sex, environment, etc. Studies in recent years have shown that the ideal body temperature, in which the body functions normally, would be between 36 and 37 °C. Body temperature regulation is a strict process [4-7]. In critically ill patients, an abnormal body temperature is associated with adverse clinical outcomes [8-14]. Furthermore, body temperature abnormalities are used to identify certain phenotypes of the immune response to infections [15] and in evaluating the body's response to certain interventions (e.g. antibiotic or anti-inflammatory therapies) [16-17].

Body temperature monitoring methods are classified into invasive methods and non-invasive methods. Thus, as non-invasive methods of temperature measurement we have: axillary thermo, infrared tympanic and temporal scanner, but their accuracy in estimating the central body temperature in intensive care patients is uncertain [18-22]. The invasive methods of temperature measurement, such as intravenous and intravesical catheters, provide accurate and continuous monitoring of core body temperature, particularly in critically ill patients, in surgical settings, or in situations where accurate temperature control is vital [23-26]. The invasive procedures involving catheter insertion may cause discomfort or pain to the patient. Appropriate anaesthesia or pain management strategies may be used to alleviate patient discomfort during and after the procedure.

Traditional thermometry methods, while effective, often lack the adaptability required for continuous or remote monitoring. Recent advancements in microcontroller technology, particularly with open-source platforms as Arduino,

THE ANNALS OF “DUNAREA DE JOS” UNIVERSITY OF GALATI
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N°. 3 - 2024, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2024.3.03

have introduced a novel approach for building cost-effective and customizable temperature measurement systems [27-32]. By integrating Arduino with precision sensors, such as infrared (IR) or contact-based temperature sensors, it is possible to construct versatile devices that provide real-time body temperature readings with a high degree of accuracy [33-36]. The MLX90614 sensor is a particularly useful tool in the field of medical engineering, providing an accurate and non-invasive method of measuring the temperature of the body and medical devices using infrared technology. This type of sensor has a wide range of applications in medical engineering. Primarily, it is used to measure body temperature without the need for direct skin contact, providing an accurate and hygienic alternative to traditional thermometers [38-41]. This is particularly useful in monitoring the health status of patients during hospitalization or on an outpatient basis. The sensor can also be used for temperature monitoring in various medical devices such as: incubators, infusion pumps or medical imaging devices [42-46].

2. Experimental procedure

The operation of infrared thermometers is based on the phenomenon of absorption of infrared radiation by objects in the field of view of the device. Infrared radiation, similar in behavior to visible light, can be focused, reflected or absorbed. Using an optical lens, infrared thermometers direct infrared radiation from the object being analysed to a thermal detector, known as a thermopile.

As indicating the block diagram proposed in Figure 1, the temperature monitoring system comprises: Arduino Uno board, MLX90614 temperature sensor, OLED SH1306 screen, breadboard and wires with different types of connections. Within the circuit, essential connections include a screen for displaying data, the MLX sensor, and an Arduino board used as the central control unit. The communication between the sensor and the board is carried out via the SDA and SCL pins, according to the I2C communication protocol. This protocol allows multiple devices to be connected to the same data and clock line, thus simplifying the circuit management. The circuit is powered at 5 volts DC. Through this complex configuration, the infrared thermometer asserts itself as an accurate and efficient measurement tool, providing relevant and necessary information in a variety of applications, including body temperature monitoring and industrial process control.

Body temperature data collected by the MLX90614 non-contact infrared temperature sensor is instantly displayed on the project's OLED screen. This list is achieved by detecting infrared radiation emitted by the human body by the MLX90614 sensor, without the need for direct contact. Using advanced technology, this system allows immediate interpretation and display of temperature data, eliminating any perceptible delay. With this technological solution, body temperature monitoring is instantaneous, and the smallest temperature fluctuations are detected and interpreted by the sensor. Compared to traditional thermometers, which may involve a waiting time in obtaining results, this system provides continuous and accurate temperature monitoring, providing real-time information for health assessment. Infrared technology allows the detection of thermal radiation emitted by objects and its transformation into electrical signals, which are subsequently processed to provide accurate data about the object's temperature.

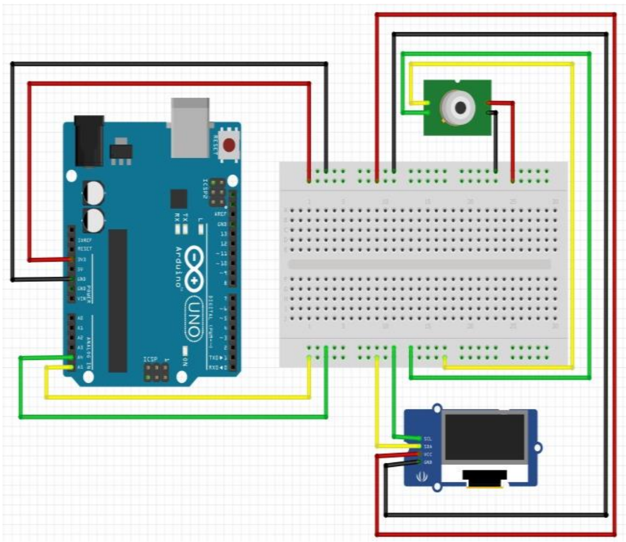

Fig. 1. *The block diagram of the proposed system architecture*

The MLX90614 sensor (Figure 2) uses this technology to identify and interpret thermal radiation emitted by objects at a certain frequency, associated with their temperature. This complex device consists of an infrared detector through which thermal radiation is captured and then converted into electrical signals, and a processing circuit that interprets these signals to provide accurate temperature readings. The ambient temperatures and object temperatures are available in RAM with a resolution of 0.01 °C. The calibration of the MLX90614 sensor is in extended temperature ranges, starting from -40 °C to 125 °C for ambient temperature and starting from -70 °C to 380 °C for object temperature. The final temperature resulting represents the average temperature of all objects in the field of view of the sensor with an accuracy standard of ±0.5 °C. It is important to mention is that for medical applications, there is a version with an accuracy of ±0.2 °C in a limited temperature range around the human body.

Fig. 2. *The MLX90614 sensor pin connections*

The MLX90614 has in its component a built-in optical filter that has the ability to stop visible light and near-infrared light, these being in the advantage of making the most accurate measurements. Also, thanks to this filter, the sensor is immune to ambient light and sunlight. In Figure. 3 is presented the OLED screen pin connections.

Fig. 3. *The OLED screen pin connections*

3. Results and discussions

Once the components are connected, the USB cable must be mounted between the Arduino board and the laptop. The following will be selected from the Arduino menu: the corresponding port and the board, then to test the created code to find the errors and be able to solve them. The code steps are: introducing libraries, defining variables, and the two essential functions, void setup and void loop.

In Figure 4 is represented the sensor connections to the Arduino Uno board. In Figure 5 is depicted the connection between the OLED screen and the system components to the breadboard The monitoring system display and the results on the OLED screen are presented in Figure 6. The OLED screen pin connections are: GND, VCC, SDA and SCL. GND (Ground) is the screen's ground terminal and should be connected to any available GND pin on the Arduino board to establish a common reference for the circuit. VCC (Voltage Common Collector) is the screen's power terminal and connects to the Arduino board’s power source, set to 5V. SDA (Serial Data) and SCL (Serial Clock) are the screen's serial communication terminals, which connect to the Arduino board's A4 (Serial Data) and A5 (Serial Clock) pins, respectively. These connections enable the Arduino to communicate with the OLED SH1306 display via the I2C protocol.

The device output verification procedure includes comparing the device output values to the output values from an infrared thermometer device. To make this comparison, several measurements were made. Body temperatures were measured at the index finger using two different thermometers. Each body region was measured five times, with a time interval of 15 minutes between measurements (Figure 7). For each thermometer, the measurements were performed three times (Table 1). The differences between the measurements registered by the two thermometers were analysed to validate the results of the proposed system. To validate the results is important to verify if the temperature of the object is much lower than the ambient temperature (in this case, by more than 5 °C). This threshold can be adjusted as is necessary. If it is not a valid object it will be display the message "No Object" on the OLED screen and in the serial monitor. If it is a valid object, will be display the temperature of the object on the OLED screen and in the serial monitor.

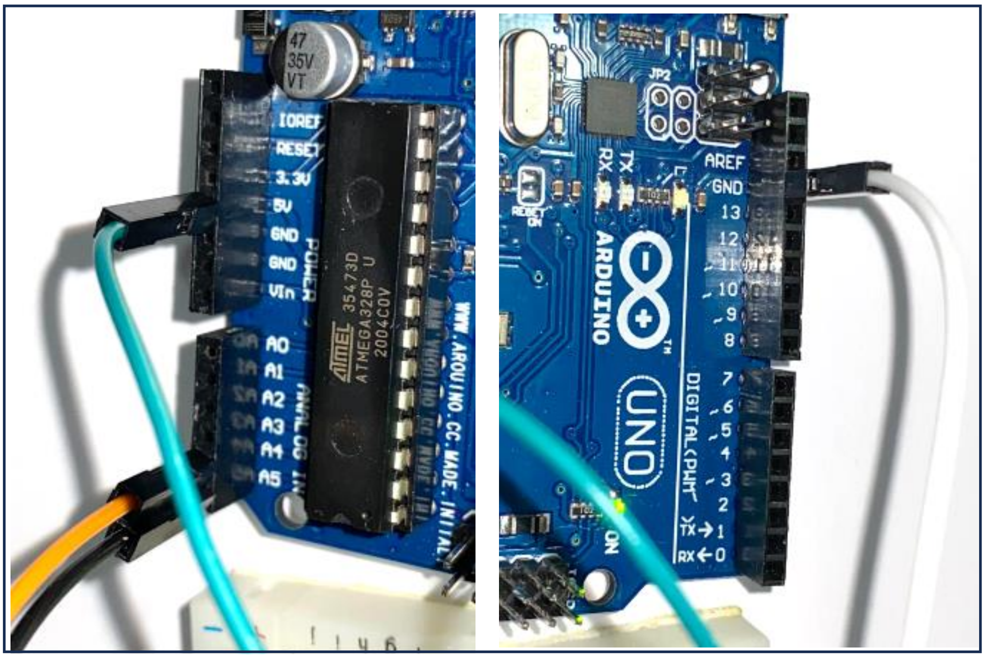

Fig. 4. *The sensor connections to the Arduino Uno board*

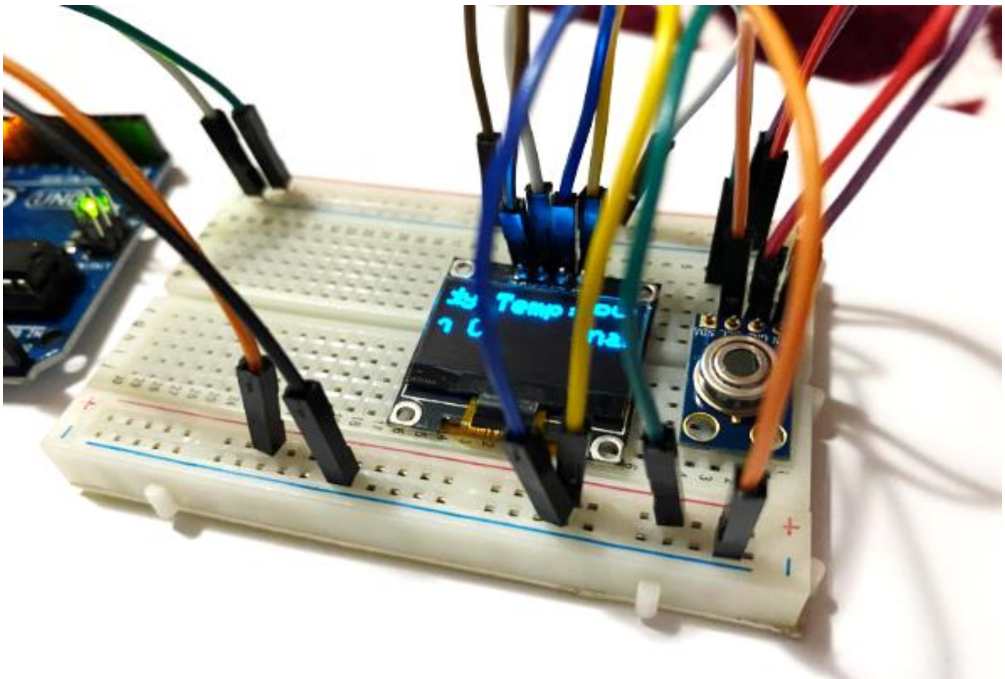

Fig. 5. *Connecting the OLED screen and the system components to the breadboard*

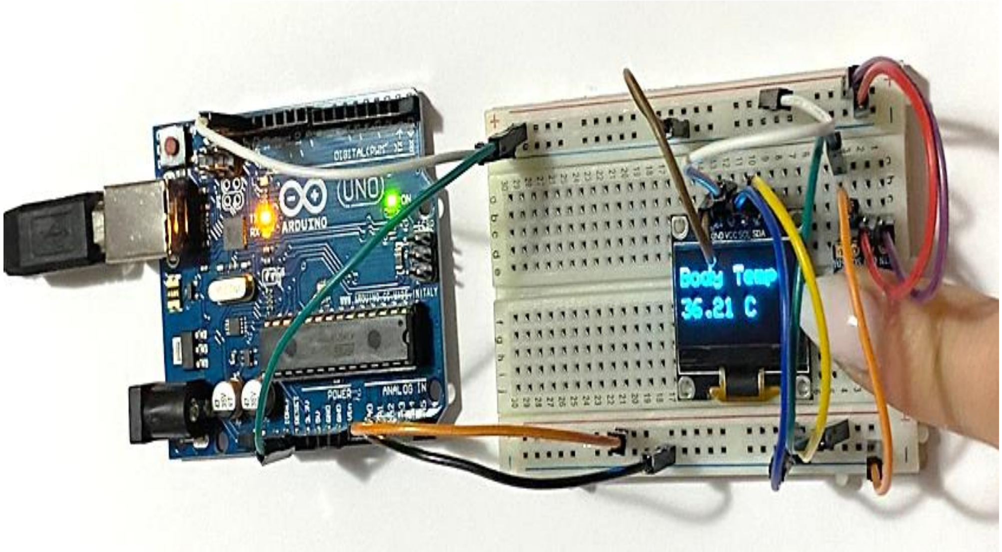

Fig. 6. *Monitoring the system display and the results on the OLED screen*

Table 1. *The comparison of measurements made with the proposed system and an infrared thermometer*

No. det.	Thermometer 1 (°C)	Thermometer 2 (°C)	Difference (°C)
1	36.5	36.6	+0.1
2	36.6	36.6	+0.0
3	36.6	36.7	+0.1
4	36.5	36.6	+0.1
5	36.7	36.8	+0.1
6	36.4	36.5	+0.1
7	36.5	36.6	+0.1
8	36.5	36.6	+0.1
9	36.4	36.5	+0.1
10	36.6	36.7	+0.1
11	36.7	36.8	+0.1
12	36.8	36.9	+0.1
13	36.7	36.8	+0.1
14	36.7	36.8	+0.1
15	36.8	36.9	+0.1
16	36.6	36.7	+0.1
17	36.7	36.8	+0.1
18	36.6	36.7	+0.1
19	36.6	36.7	+0.1
20	36.7	36.8	+0.1
21	36.8	36.9	+0.1
22	36.9	37.0	+0.1
23	36.8	36.9	+0.1
24	36.8	36.9	+0.1
25	36.9	37.0	+0.1
26	36.7	36.8	+0.1
27	36.8	36.9	+0.1
28	36.7	36.8	+0.1
29	36.7	36.8	+0.1
30	36.7	36.8	+0.1

4. Conclusions

In conclusion, both thermometers give very similar results, with minor differences of 0.1 °C. This suggests that both devices are suitable for measuring body temperature and can be used interchangeably without compromising data accuracy.

Body temperature measurements showed stability and consistency both between different measurements of the same subject and between different subjects. The minor fluctuations observed are consistent with normal variations in human body temperature and do not indicate any significant abnormality.

The analysis of the results obtained from temperature monitoring in various experimental situations provided valuable information about the performance of the system.

Using a body temperature monitoring device using the Arduino platform has multiple advantages and applications.

1. Such a device can detect increases in body temperature immediately, enabling rapid interventions, which are essential in medical emergencies, as a real-time monitoring (rapid fever detection).

2. Enables constant temperature monitoring without the need for repeated manual intervention, providing a clear picture of temperature fluctuations throughout the day.

3. The ability to add additional functionality, such as alarming when a temperature threshold is exceeded or data transmission via the Internet.

Using the Arduino platform for body temperature monitoring provides an affordable, customizable and efficient solution for a wide range of applications, from personal care to patient monitoring in hospitals, this type of device can significantly contribute to improving health and safety.

References

[1]. Jasnic N., Djordjevic J., Vujovic P., Lakic I., Djurasevic S., Cvijic G., *The effect of vasopressin 1b receptor (V1bR) blockade on HPA axis activity in rats exposed to acute heat stress*, J Exp Biol., 216(Pt 12), p. 2302-2307, 2013.

[2]. Son Y. L., Ubuka T., Tsutsui K., *Regulation of stress response on the hypothalamic-pituitary-gonadal axis via gonadotropin-inhibitory hormone*, Front Neuroendocrinol, 64:100953, 2022.

[3]. Sheng J. A., Bales N. J., Myers S. A., Bautista A. I., Roueinfar M., Hale T. M., Handa R. J., *The Hypothalamic-Pituitary-Adrenal Axis: Development, Programming Actions of Hormones, and Maternal-Fetal Interactions*, J Frontiers in Behavioral Neuroscience, 14, 2021.

[4]. Sessler D. I., *Temperature monitoring and perioperative thermoregulation*, Anesthesiology, 2008, Aug;109(2), p. 318-338, 2008.

[5]. Osilla E. V., Marsidi J. L., Shumway K. R., *et al.*, *Physiology, Temperature Regulation: StatPearls*, 2024.

[6]. Crucianelli L., Salvato G., Nagai Y., Quadt L., Critchley H., *Sudomotor function, thermoregulation and electrodermal control in the human brain*, Editor(s): Jordan Henry Grafman, Encyclopedia of the Human Brain (Second Edition), Elsevier, p. 357-373, 2025.

[7]. Shido O., Matsuzaki K., Katakura M., *Chapter 28 - Neurogenesis in the thermoregulatory system*, Editor(s): Andrej A. Romanovsky, Handbook of Clinical Neurology, Elsevier, vol. 156, p. 457-463, 2018.

[8]. Kushimoto S., Yamanouchi S., Endo T., Sato T., Nomura R., Fujita M., Kudo D., Omura T., Miyagawa N., Sato T., *Body temperature abnormalities in non-neurological critically ill patients: a review of the literature*, J Intensive Care, 2(1):14, 2014.

[9]. Erkens R., Wernly B., Masyuk M., Muessig J. M., Franz M., Schulze P. C., Lichtenauer M., Kelm M., Jung C., *Admission Body Temperature in Critically Ill Patients as an Independent Risk Predictor for Overall Outcome*, Med Princ Pract., 29(4), p. 389-395, 2020.

[10]. Tan D. J., Chen J., Zhou Y., *et al.*, *Association of body temperature and mortality in critically ill patients: an observational study using two large databases*, Eur J Med Res 29, 33, 2024.

[11]. Sakkat A., Alquraini M., Aljazeeri J., Farooqi A. M., Fayez A., Waleed A., *Temperature control in critically ill patients with fever: A meta-analysis of randomized controlled trials*, Journal of Critical Care, vol. 61, p. 89-95, 2021.

[12]. Faulds A., Meekings M., Tim T., *Temperature management in critically ill patients*, JF Continuing Education in Anaesthesia Critical Care & Pain JO Contin Educ Anaesth Crit Care Pain, VO 13 IS 3 SP 75 OP 79, 2013.

[13]. Luo W., Cao L., Wang C., *Low body temperature and mortality in critically ill patients with coronary heart disease: a retrospective analysis from MIMIC-IV database*, Eur J Med Res, 28, 614, 2023.

[14]. Cutuli S. L., *et al.*, *Accuracy of non-invasive body temperature measurement methods in critically ill patients: a prospective, bicentric, observational study*, Critical Care and Resuscitation, vol. 23, issue 3, p. 346-353, 2021.

[15]. Liu B., Zhou Q., *Clinical phenotypes of sepsis: a narrative review*, J Thorac Dis., 2024 Jul 30, 16(7), p. 4772-4779, 2024.

[16]. Chakraborty R. K., Burns B., *Systemic Inflammatory Response Syndrome*, StatPearls Publishing, 2024.

[17]. Wrotek S., LeGrand E. K., Dzialuk A., Alcock J., *Let fever do its job: The meaning of fever in the pandemic era*, Evolution, Medicine, and Public Health, vol. 9, issue. 1, p. 26-35, 2021.

[18]. Lawson L., *et al.*, *Accuracy and Precision of Noninvasive Temperature Measurement in Adult Intensive Care Patients*, American journal of critical care: an official publication, American Association of Critical-Care Nurses, 16, p. 485-96, 10.4037/ajcc2007.16.5.485., 2007.

[19]. Nascimento A., Biachi C., Lyra F. B., Gnatta F., Poveda J. R., *Evaluation of different body temperature measurement methods for patients in the intraoperative period*, Revista Latino-americana De Enfermagem, 32, e4143, 2024.

[20]. Daniel J. Niven, Jonathan E. Gaudet, Kevin B. Laupland, *et al.*, *Accuracy of Peripheral Thermometers for Estimating Temperature: A Systematic Review and Meta-analysis*, Ann Intern Med., 163, p. 768-777, 2015.

[21]. Zhao Y., Bergmann J. H. M., *Non-Contact Infrared Thermometers and Thermal Scanners for Human Body Temperature Monitoring: A Systematic Review*, Sensors, 23, 7439, 2023.

[22]. Wagner M., Lim-Hing K., Bautista M. A., *et al.*, *Comparison of a Continuous Noninvasive Temperature to Monitor Core Temperature Measures During Targeted Temperature Management*, Neurocrit Care, 34, p. 449-455, 2021.

[23]. Drumheller B. C., Stein D. M., Scalea T. M., *Use of an intravascular temperature control catheter for rewarming of hypothermic trauma patients with ongoing hemorrhagic shock after* *combined damage control thoracotomy and laparotomy: A case series*, Injury, 49(9), p. 1668-1674, 2018.

[24]. Schmutzhard E., *et al.*, *Safety and efficacy of a novel intravascular cooling device to control body temperature in neurologic intensive care patients: a prospective pilot study*, Crit Care Med., 30(11), p. 2481-8, 2002.

[25]. Rubia-Rubia J., Arias A., Sierra A., Aguirre-Jaime A., *Measurement of body temperature in adult patients: Comparative study of accuracy, reliability and validity of different devices*, International Journal of Nursing Studies, 48, issue 7, p. 872-880, 2011.

[26]. Gao Y. L., Ming J., Miaowen Z. Yang, Ji. X., *A narrative review of intravascular catheters in therapeutic hypothermia*, Brain Circulation, 10(1), p. 11-20, Jan-Mar 2024.

[27]. Ashraf S., Khattak S. P., Iqbal M. T., *Design and Implementation of an Open-Source and Internet-of-Things-Based Health Monitoring System*, J. Low Power Electron. Appl., 13, 57, 2023.

[28]. Abdulmalek S., *et al.*, *IoT-Based Healthcare-Monitoring System towards Improving Quality of Life: A Review*, Healthcare (Basel), 10(10), 1993, 2022.

[29]. Junaid S. B., Imam S., *et. al.*, *Recent Advancements in Emerging Technologies for Healthcare Management Systems: A Survey*, Healthcare (Basel), 10(10), 1940, 2022.

[30]. Pronami Bora, *et al.*, *Smart real time health monitoring system using Arduino and Raspberry Pi*, Materials Today: Proceedings, vol. 46, 9, p. 3855-3859, 2021.

[31]. Sumathy B., *et al.*, *Wearable Non-invasive Health Monitoring Device for Elderly using IOT*, IOP Conf. Ser.: Mater. Sci. Eng., 1012, 012011, 2021.

[32]. Deng Z., Guo L., Chen X., Wu W., *Smart Wearable Systems for Health Monitoring*, Sensors, 23(5), 2479, 2023.

[33]. Ahmed Asif, Abdullah Mohd Noor, Taib Ishkrizat, *Design of a contactless body temperature measurement system using Arduino*, Indonesian Journal of Electrical Engineering and Computer Science, 19, 1251, 2020.

[34]. Kimmo K., *et al.*, *Infrared Temperature sensor system for mobile devices*, Sensors and Actuators A Physical, 158, p. 161-167, 2010.

[35]. Wang K., *et al.*, *Non-contact infrared thermometers for measuring temperature in children: Primary care diagnostic technology update*, Br. J. Gen. Pract., 64, p. e681-e683, 2014.

[36]. Goh Nicholas, *et al.*, *Design and Development of a Low Cost, Non-Contact Infrared Thermometer with Range Compensation*, Sensors, 21, 3817, 2021.

[37]. Ng K. G., Wong S. T., Lim S. M., Goh Z., *Evaluation of the Cadi ThermoSENSOR wireless skin-contact thermometer against ear and axillary temperatures in children*, J Pediatr Nurs., 25(3), p. 176-86, 2010.

[38]. Zhang J., *Development of a Non-contact Infrared Thermometer*, 10.2991/aetr-17.2018.59, 2018.

[39]. Nuraidha A. C., *et al.*, *Development of a non-contact infrared thermometer as a prevention Covid-19*, AIP Conference Proceedings, vol. 2491, no. 1, AIP Publishing, 2023.

[40]. Long Guangli, *Design of a Non-Contact Infrared Thermometer*, International Journal on Smart Sensing and Intelligent Systems, 9, p. 1110-1129, 10.21307/ijssis-2017-910, 2016.

[41]. Chunyan Li, Jiaji Wang, Shuihua Wang, Yudong Zhang, *A review of IoT applications in healthcare*, Neurocomputing, vol. 565, 127017, 2024.

[42]. Aya-Parra, *et al.*, *Monitoring System for Operating Variables in Incubators in the Neonatology Service of a Highly Complex Hospital through the Internet of Things (IoT)*, Sensors, 23, 5719, 10.3390/s23125719, 2023.

[43]. Ryanto I. Komang Agus Ady, Maneetham Dechrit, Triandini Evi, *Developing a smart system for infant incubators using the internet of things and artificial intelligence*, International Journal of Electrical and Computer Engineering, v. 14, n. 2, p. 2293-2312, 2024.

[44]. Bhujbal R., *et al.*, *Smart ASHeR Infant Incubator for Accurate Monitoring and Control*, 8, p. c531-c536, 10.1729/Journal.27909, 2021.

[45]. Puvindra Y., *et al.*, *Enhancement Drip Dose Infusion Accuracy Based on Optocoupler and Microcontroller Sensor*, International Journal of Advanced Health Science and Technology, 2, 10.35882/ijahst.v2i4.135, 2022.

[46]. Subrata A., *et. al.*, *Low-Cost Early Detection Device for Breast Cancer based on Skin Surface Temperature*, IT Journal Research and Develop., 9, p. 27-37. 10.25299/itjrd.2024.16034, 2024.