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Remote Patient Body Temperature Monitoring Based-IEEE802.11a Internet of Things (IoT)

***Abstract**. The coronavirus disease (COVID-19) situation keeps continued from the end of 2019 until right now. It is a deadly virus that kills many humans. Thailand's solutions have urged the public to be confident about the Government handling the 2019-novel Coronavirus. This research is to respond to the policy of promoting and developing innovation that is up to date, and it is a part of preventing epidemics related to the respiratory system. The proposed Internet of Things (IoT) Remote Patient Body Temperature Monitoring (RPBTM) brings the concept of an embedded infrared sensor with IEEE802.11a standard through the Internet of medical promotion platform. The system consists of distancing infrared body temperature MLX90614 DCI sensor embedded functional programming with IEEE802.11a WiFi microcontroller. To achieve the prototype's efficiency, the results are demonstrated as the following issues; 1) the accuracy performance test in terms of the prototype's calibration and 2) the temperature measurement of each body part. The findings were found that the proposed RPBTM device has an error compared to the standard device, only 0.56 %. Moreover, the prototype measured the body parts such as the man's forehead, palm, and armpit and found that the forehead and armpit temperatures have a positive relationship at a high relationship (.860). Meanwhile, the forehead and palm temperatures have a positive relationship at a moderate level (.473). Hence, it can be hypothesized that the body part that should be selected to detect the body temperature is the forehead and armpit because it is close to absolute body temperature.*

*Streszczenie. Sytuacja z koronawirusem (COVID-19) trwa od końca 2019 roku do chwili obecnej. To śmiertelny wirus, który zabija wielu ludzi. Rozwiązania Tajlandii zachęciły opinię publiczną do pewności, że rząd zajmuje się koronawirusem z 2019 roku. Badania te mają odpowiadać na aktualną politykę promowania i rozwoju innowacji, wpisując się w zapobieganie epidemiom związanym z układem oddechowym. Proponowane zdalne monitorowanie temperatury ciała pacjenta (RPBTM) Internetu rzeczy (IoT) wprowadza koncepcję wbudowanego czujnika podczerwieni ze standardem IEEE802.11a za pośrednictwem platformy Internetu promocji medycyny. System składa się z odległościowego czujnika temperatury ciała na podczerwień MLX90614 DCI z wbudowanym programowaniem funkcjonalnym z mikrokontrolerem WiFi IEEE802.11a. Aby osiągnąć wydajność prototypu, wyniki przedstawiono jako następujące kwestie; 1) test wydajności dokładności w zakresie kalibracji prototypu oraz 2) pomiar temperatury każdej części ciała. Ustalono, że proponowane urządzenie RPBTM ma błąd w porównaniu ze standardowym urządzeniem, wynoszący zaledwie 0,56%. Co więcej, prototyp zmierzył części ciała mężczyzny, takie jak czoło, dłoń i pacha, i stwierdził, że temperatura czoła i pod pachami wykazuje dodatnią zależność przy wysokim stosunku (0,860). Tymczasem temperatura czoła i dłoni wykazuje dodatnią zależność na umiarkowanym poziomie (0,473). Można zatem postawić hipotezę, że część ciała, którą należy wybrać do wykrywania temperatury ciała, to czoło i pacha, ponieważ jest ona zbliżona do bezwzględnej temperatury ciała. (**Zdalne monitorowanie temperatury ciała pacjenta w oparciu o IEEE802.11a Internet rzeczy (IoT)**)*

Keywords: COVID-19, RPBTM, IEEE802.11a,
Słowa kluczowe: pomiar temperatury, Internet Rzeczy, monitorowanie

Introduction

At the end of March 2021 in Thailand, the COVID-19 outbreak was at its "peak" the number of infections increased by hundreds each day after a "super spreader" was found in the boxing stadium and entertainment venues. This incident was followed by migrant workers returning to their home provinces when the Government announced the closure of shops in Bangkok. According to the news of the epidemic, a newly graduated doctor works in a hospital in the south, preparing to take care of workers returning to their domicile who may be sick from COVID-19, but he did not expect that he would become a risk of infection himself—finding an infected person in a small hospital, which lacks this protective equipment. As a result, the hospital has to lose personnel, including nurses and health workers who contact patients for the quarantine and treatment of COVID-19; by the day the patient was found, everyone is wearing only a mask.

Hence, social distancing is a critical topic that can apply as well to this situation. Social distancing, called "physical distancing," means keeping a safe space between yourself and other people who are not from your household. To practice social or physical distancing, stay at least 6 feet (about two arm lengths) from other people in indoor and outdoor spaces, not from your household. Social distancing should be practiced in combination with other everyday preventive actions to reduce the spread of COVID-19, including wearing masks, avoiding touching the face with unwashed hands, and frequently washing hands with soap and water for at least 20 seconds.

Why practice social distancing: COVID-19 spreads mainly among people who are in close contact (within about 6 feet) for a prolonged period. Spread happens when an infected person coughs, sneezes, or talks, and droplets from their mouth or nose are launched into the air and land in the mouths of people nearby. The droplets can also be inhaled into the lungs. Recent studies indicate that people infected but do not have symptoms likely also play a role in the spread of COVID-19. Since people can spread the virus before they know they are sick, it is vital to stay at least 6 feet away from others when possible [1]. Nevertheless, the "social distancing" cannot be used for medical personnel cases because they need to look after and almost always work with their risky COVID-19 patients.

The IoT brings new opportunities for telemedical platforms. It is targeted to have continuous real-time communicability with the patient, enhanced interoperability of applications, and a detailed case history enabling physicians to adopt reasonable treatment procedures [2, 3]. This feature would improve healthcare delivery through accurate data compilation and automated workflow, substantially reducing patients' costs and waiting time. This paper applies the RPBTM system using an IoT Based-IEEE801.11a standard to solve the abovementioned problem statement. The proposed prototype is helpful for telemedical treatment for observing monitoring away from COVID-19 patients. It is implemented concerning accuracy with a distancing monitoring system using the Internet for the telemedical platform. Therefore, an idea of the proposed DBTB system will be fulfilled somehow the requirements of the medical personnel in the current situation. This solution reduces the medical personnel' s infection from Coronavirus disease with acceptable measurement quality with low erroneous.

This paper is organized into the following sections. Firstly, the concept of the proposed novelty RPBTM system included the hardware and cloud computing information. Moreover, the prototype's reliability test also provides the experimental results on standard accuracy test and experimental results on body organs—lastly, the conclusions.

Concept of the Proposed Novelty RPBTM System

Before starting the content presentation, the research algorithm is proclaimed as follows. The algorithm framework of this research started from studying the problem statements based on the current situation, referring to the introduction section. Secondly, review the related works which are added to the contents of each Section. After that, the invention is created based on development and improvement from the previous study for hardware and software creations. In addition, the hardware will be tested based on the accuracy of the proposed medical instrument using the IoT platform, which is a significant issue before deploying in actual applications. Sezdi. M has presented the performance analysis for medical devices by mentioning the performance test of accurate measurement. An invention that used to be applied in the medical Section must be referred to as the standard measurement system [4]. Furthermore, it is included software programming performance for further improvement should be added in future work.

The proposed RPBTM system came out based on the problem statement with the COVID-19 situation time. However, with the seriousness of Coronavirus that occurred in 2019 time, an incredible new way of living has happened. Namely, people at high risk in this era of the Coronavirus are doctors and healthcare staff. Therefore, the RPBTM system is creative to reduce the infection risk from medical treatment services in hospitals. The prototype is a pilot project that brings the IoT technology platform and high-performance infrared body temperature sensor, which is specified for medical measuring.

Figure 1 presents the structure architecture of the proposed RPBTM system. Internet for medical promotion is possible to be advance shortly. The RPBTM system consisted of two parts, which are hardware and software. The principal concept of IoT work is to connect a sensing hardware device and a cloud internet network. Moreover, a user has also been involved in the IoT system in applying the information and know-how they use the provided IoT intelligent system. Thus, all parties are connected and supported by each other. However, even though we are in machine-to-machine communication, called the "M2M" era, humans still need to be included in the IoT cycle.

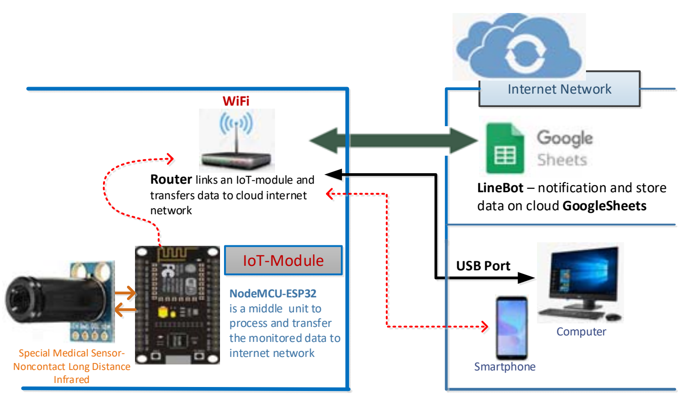

Fig.1 The architecture of the proposed RPBTM framework

Cloud computing is a part of a system service that covers the computing power, storage unit function, and various online systems from service providers to simplify installation, and maintenance, save time and reduce the cost of building our systems and networks.

1. Hardware Design

Typically, body temperature measurement can be divided into types, which are contact and non-contact. In this article, the non-contact measurement uses infrared radiation to measure the body temperature and does not require a direct touch. Additionally, this method of measurement can be read quickly and accurately. Figure 2 presents the schematic circuit between the IoT microcontroller and infrared body temperature measuring. Inside the hardware, the circuit module is embedded programming function design, described in the DBTB programming design (Section 3).

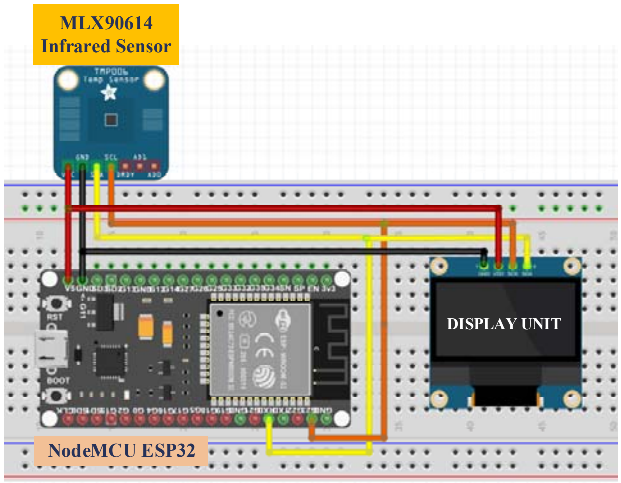

Fig.2 Schematic circuit of the hardware device

The sensing device's priority in this circuit prototype is the medical infrared thermometer sensor MLX90614 DCI chip. It works in high performance with maximum long-distance detection of 50 cm [5], the appropriate chip adopted in the RPBTM system. Moreover, it is a small size, and it is not very expensive compared to the specified performance of high accuracy of 0.5 ℃ over wide temperatures from 0 ℃ to 50 ℃, which is the rank for medical accuracy calibration. In the actual application, the MLX90614 DCI sensor chip is also suitable for the in-patient department because it can work in the sleeping mode for reduced power consumption, and meanwhile, it does not disturb the patient all the time with LED blinking onboard device that is installed nearby the patient bed.

In recent years, non-contact measurement methods have been used for medical, environmental monitoring, home automation, automotive electronics, aerospace, and military applications [6, 7, 8].

Increasing the prevalence of Coronavirus is one of the significant factors that has created the need to adopt a distancing body temperature monitoring service and increase home supervision in future work. As a result, the remote medical monitoring market is expected to establish a significant pre-and post-treatment management presence. Moreover, the further utilization of artificial can be effectively and remotely monitored, with their acute diseases detected, diagnosed, prevented, and treated for smooth and continuous operation [9]. Figure 2 presents the framework structures of the RPBTM system. It consists of an IoT-monitoring module, WiFi router, internet network platform, intelligent devices, and users. These compositions are related to body monitoring operation—the actual application of the proposed system, as shown in Figure 3.

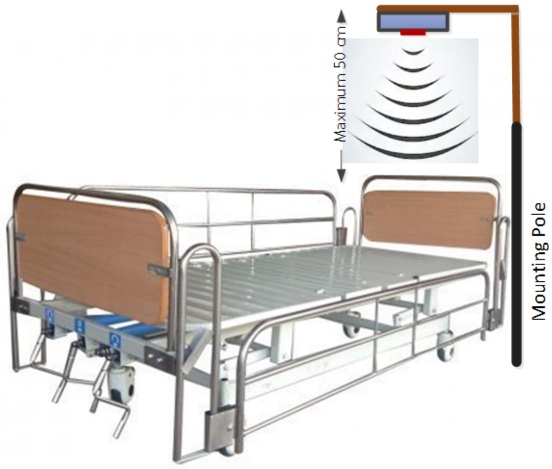

Fig. 3 The RPBTM device installed in the patient's bed

Figure 3 demonstrates the RPBTM prototype. It is a distancing infrared temperature monitoring module attached to a pole beside the patient's bed. Based on the qualification of sensor detection, it can sense the body temperature at a distance of 50 cm. In actual use, the monitoring pole can be adjusted according to the bed level. The IoT architecture applied for healthcare applications aids in integrating the advantages of IoT technology and cloud computing with the medical section field [10]. In addition, it also lays out the protocols for the transmission of the patient's information from numerous sensors and medical devices to a given healthcare network. Namely, the topology of the IoT healthcare system is coherently connected in a healthcare environment [11, 12, 13].

2. Cloud Computing

The RPBTM system took cloud computing as the migration of monitoring applications. It is a process within the framework, as shown in Figure 1 above. The information is stored in the cloud provider without the user who has to take care of hardware devices, saving cost and time. It only connects via the Internet, including controlling system various resources that users can easily control.

In this study, the hardware device with application on a smart device is related using Platform-as-a-Service (PaaS). Platform-as-a-Service (PaaS) is a cloud-based, easily accessible application on a platform where features can be deployed, but it is unlimited it unable to meet the detailed work requirements and high security. Thus, this type of cloud computing matches the application at the beginning of trying out the IoT-monitoring prototype. Moreover, Software-as-a-Service (SaaS) is also used as a cloud system where users can access applications without having to install them on their server resources, enabling application monitoring.

Prototype's Reliability Test

This Section demonstrates the DBTB device's test results, which are divided into main parts; 1) Experimental results on the standard accuracy test and 2) Experimental results on the body parts test. The details are presented as follows.

1. Experimental Results on Standard Accuracy Test

In this study, the MLX90614 DCI chip was adopted to use in medical applications. It is similar to the research article of B. Wasana [14], in which she uses the MLX90614 DCI chip sensor for wireless automatic body temperature sensing with non-contact infrared via the Internet for medical promotion. Namely, the experimental results of the proposed device and standard device under Thai Industrial Standard (TIS). It was found that both devices have an average of different temperature values of 0.56% with 60 times testing. The calibration test on the prototype can confirm that it is precisely accurate with a low error percentage. The results are plotted as shown in Figure 4.

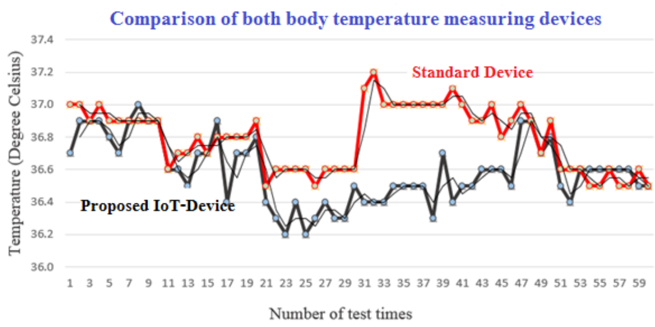

Fig. 4 The calibration test between the proposed IoT device and the standard one

2. Experimental Results on Body Organs

This Section demonstrates the experimental results on the body temperature measurement of human parts. There are three body parts for temperature testing, which are the forehead, palm, and armpit. These results compare the differences between the three men of the same age, environment temperature, and limited-time test.

This research section is related to the review article of Ivayla I. Geneva *et al*. Namely, each part of the human body is at a different temperature, about ±2 standard deviations. This article mentions the temperature at an axillary, which generally has a temperature between 35.01-36.93 °C [15]. This temperature range is the people aged lower than 60 years old, regarding the older adults have their body temperature lower by 0.23 °C. Moreover, if the human body has a fever, the measured body temperature will be an average axillary temperature of 37.0 °C with an upper limit of normal defined as 38.0 °C [16].

(a) Palm test (b) Forehead test

Fig. 5 The temperature test of the body parts measured by the proposed prototype

Figure 5 shows the body temperature test on palm and forehead tests using the proposed prototype before taking it applies to an actual patient in a hospital. In the previous research on the development of IoT heartbeat and body temperature monitoring systems for community health volunteers by N. Saowakhon *et al*., the body temperature using ThingSpeak-IoT platform in real-time monitoring also mentioned the body temperature. The practical information was transferred through the Line application. Moreover, the android application also can keep track of all measuring devices [17]. In this work, the author applied the microcontroller NodeMCU-IoT device to connect with the internet network. That information will be kept in google Sheets according to the time set in every hour. Thus, the information observed will be continued when checking back to record the patient as well. The Google sheet was used to collect the patient's body temperature end device continuously in actual use. Only this test authors have tried to design to collect the information as fast as possible to receive accurate data using the Google Sheet on the cloud internet network.

Conclusions

This paper proposes the algorithm of the novelty DBTB system using an IoT-cloud computing platform. The prototype was inspired based on the problem statement of the COVID-19 situation, which took a long time around the world. Thus, it can be fulfilled the requirements and the needs of medical personnel. In the future, this solution can be helpful for medical treatment because plenty of medical staff, nurses, and doctors have suffered from their duty work regarding they need to work in the hospital, which has more chances to contact COVID-19 patients and risk of the virus. The proposed RPBTM impacts the medical Section regarding it brings the concept of treatment distancing with more efficiency of real-time monitoring details and the storage of information data as a systematic folder. The information can be searched and opened up for use at any time whenever the user requires it.

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REFERENCES

[1] Madane. S., Chitre. D, Social Distancing Detection and Analysis through Computer Vision, *2021 6th International Conference for Convergence in Technology*, (2021), pp. 1-10

[2] Albahri A. S., Alwan. J. K., Taha. Z. K., Ismail. S. F., Hamid. R. A., Zaidan. A. A., Albahri. O. S., Zaidan. B. B., Alamoodi. A. H., Alsalem. M. A., IoT-Based telemecine for desease prevention and health promotion: State-of-the-Art, *Journal of Network and Computer Applications*, (2020), pp. 1-52

[3] Oryema. B., Design and implementation of an interoperable messaging system for IoT healthcare services, *14th IEEE Annual Consumer Communications and Networking Conference*, (2017), pp. 45-52

[4] Sezdi. M., Performance Analysis for Medical Devices, *Biomedical Engineering Research*, vol. 2(3), (2013), pp. 139-146

[5] DFROBIT. I2C Non-Contact IR Temperature Sensor (MLX90614-DCI)

[6] Mukul Madhukar. D., Saurabh Mukund. H., Chaya Sunil. K., Temperature Measurement using Infrared Contactless Thermal Gun, *2020 International Conference on Smart Innovations in Design, Environment, Management, Planning and Computing*, (2021), pp. 134-137

[7] Erik. H., Ashish. P., Abhiskek. M., Geert. L., Sigle-Pixel Thermopile Infrared Sensing for People Counting, *IEEE Sensor Journal*, vol. 21(4), (2021), pp. 4866-4873

[8] Juan. Z., Application of Wireless Sensor Network in Automatic Detection of Spray Disinfection in Pig Epidemic Envirionment, *2020 IEEE International Conference on Power, Intelligent Computing and System*, (2020), pp. 123-125

[9] Gonzalez. E., Pena. R., Avila. A., Vargas-Rosales. C., Munoz-Rodriguez. D., Systematic Review on Recent Advances in Health System: Development Architecture for Emergency Response, *J.Health.Eng.*, vol.2017, (2017), pp.1-13

[10] Pradhan. B., Bhattacharyya. S., Pal. K., IoT-Based Application in Healthcare Device, *Journal of Healthcare Engineering*, vol. 2021, (2021), pp. 1-18

[11] Dang. L. M., Piran. M. J., Dan. H., Min. K., Moon. H., A survey on Internet of things and cloud computing for healthcare, *Electronics*, vol. 8(7), (2019), pp. 768

[12] Wasana. B., Narongrit. S., Wireless Automatic Body Temperature Sensing System with Non-Contact Infrared Via the Internet for Medical Promotion, *Przeglad Elektrotechniczny*, (2021), pp. 132-135

[13] Long. G., Design of an Non-Contact Infrared Thermometer, *International Journal on Smart Sensing an Intelligent System*, vol. 9(2), (2016), pp. 202-205

[14] Ivayla. G., Brain. C., Tsaduq. F., and Wleed. J., Normal Body Temperature: A Systematic Review, *Open Forum Infectious Diseases*, (2019), pp. 1-7

[15] Wunderlich. CR., Das Verhalten der Eigenwaerme in Krankheiten, *Leipzig: Verlag Von Otto Wigand*, (1868)

[16] Saowakhon. N., Vipa. T., Thanakorn. K., Development of IoT Heartbeat and Body Temperature Monitoring System for Community Health Volunteer, Department of IoT Heartbeat and Body Temperature Monitoring System for Community Health Volunteer, *2020 Joint International Conference on Digital Arts, Media, and Technology with ECTI Northern Section Conference on Electrical, Electronics, Computer and Telecommunications Engineering*, (2020), pp. 106-109

[17] Kalovrektis. K., Xenakis. A., Gotsinas. A., Korinthios. I., Stamoulis. G., 802.15.4-base Efficient Wireless Sensor System Design for Monitoring Blood Oxygen and Heart Rate in IoT Medical Applications, *11th International Conference on Information, Intelligence, Systems and Applications*, (2020), pp. 1-7