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Wireless Automatic Body Temperature Sensing System with Non-Contact Infrared Via the Internet for Medical Promotion

***Abstract**. From the World Health Organization (WHO) Thailand has reported from Wuhan, China, regarding the outbreak of novel coronavirus (COVID-19). Therefore, a novel wireless automatic body temperature sensing system (WA-BTSS) is proposed. WA-BTSS consists of three main functions, which are 1) sensing mode – 2) embedded microcontroller–WiFi chip, and 3) IoT communication network. The proposed novelty WA-BTSS screen the people who enter the building with long-distance detection of 50 cm. The infrared sensor used is high quality with medical accuracy. It works together with NodeMCU-ESP8266 Microcontroller, which module is embedded with a WiFi internet chip. The proposed IoT-innovation is to facilitate users in any organization due to the high security of personnel screening personnel entering and exiting the building. The performance of both body temperature devices was tested in terms of accuracy test based on the actual experiment, and then analyze the obtained results using the statistics program. The obtained results have shown the Cronbach's Alpha value of .752, and it can be summarized that the proposed WA-BTSS performance in terms of accuracy test is positively consistent with the standard model at a significant 95 % confidence level.*

*Streszczenie. Zaproponowano nowatorski bezprzewodowy system automatycznego wykrywania temperatury ciała (WA-BTSS). WA-BTSS składa się z trzech głównych funkcji, którymi są 1) tryb wykrywania - 2) wbudowany mikrokontroler - układ WiFi oraz 3) sieć komunikacyjna IoT. Proponowana nowość WA-BTSS ekran dla osób wchodzących do budynku z detekcją 50 cm. Zastosowany czujnik podczerwieni jest wysokiej jakości z medyczną dokładnością. Współpracuje z mikrokontrolerem NodeMCU-ESP8266, którego moduł jest osadzony w chipie internetowym WiFi. Proponowana innowacja IoT ma na celu ułatwienie użytkownikom w każdej organizacji dzięki wysokiemu bezpieczeństwu personelu sprawdzającego personel wchodzący i wychodzący z budynku. Działanie obu urządzeń do pomiaru temperatury ciała przetestowano pod kątem testu dokładności na podstawie rzeczywistego eksperymentu, a następnie przeanalizowano uzyskane wyniki za pomocą programu statystycznego. Uzyskane wyniki pokazały wartość Alfa Cronbacha wynoszącą 0,752 i można podsumować, że proponowane działanie WA-BTSS w zakresie testu dokładności jest pozytywnie zgodne z modelem standardowym przy istotnym 95% poziomie ufności. (**Bezprzewodowy automatyczny system pomiaru temperatury ciała z bezkontaktową komunikacją przez Internet do celów promocji medycznej**)*

Keywords: WHO, COVID-19, WA-BTSS, IoT
Słowa kluczowe: bezkontaktowy pomiar temperatury, IoT

Introduction

The IoT is very close to human life at this moment time. Embedded systems are part and parcel of every modern electronic component and sensor. Therefore, the growth of embedded systems and the IoT has tremendous potential for many applications. Embedded systems will play an essential role in IoT platforms due to their unique characteristics and features such as real-time monitoring, low power consumption, low maintenance, and high availability are becoming the key enabler of IoT. All compositions work together, which are real-time monitoring system (RTMS), microprocessor, and microcontroller, followed by memory footprints and networking, with open worldwide on open source communities and developers [1]

This study focuses on the IoT application for measuring body temperature with non-contact infrared and transmitting data via the IoT network. This work improved compared to the previous work last few years ago [2] because it still has no COVID-19 as in the current time. Namely, some earlier works have no yet embedment IoT function into their design. Since late 2019, there has been a coronavirus epidemic [3]. Onward, Saowakhon Nookhao et al. has developed the IoT heartbeat and body temperature monitoring system for community health volunteer. The item was used for supporting groups responsible for all community members' routine health monitoring to reduce doctor and nurse works [4].

This article presents the wireless automatic body temperature sensing system. The non-contact infrared is adopted for body temperature sensing and sends information to the user through the wireless internet network. The theories involved in this work are divided into two main sections, which are 1) sensing mode – 2) embedded microcontroller – WiFi chip and 3) IoT communication network. Major players in the proposed embedded system hardware and software developments are purposed to take these transformations into their end device to benefit from developing and growing in IoT application. This paper is organized into the following sections: Section 2 Proposes the structure of the WA-BTSS system, which consists of 1) sensing mode 2) embedded microcontroller-WiFi chip and 3) IoT communication network: Section 3 Experimental results and discussions, and finally is the conclusion.

Proposed System Structure

This section clarifies the proposed wireless automatic body temperature sensing system using non-contact infrared and transmitting data via the Internet for all things network. This work's main compositions are divided into three parts: 1) sensing mode – 2) embedded system design, and 3) IoT communication network. The structure of the proposed work is shown in the component blocks, as in Figure 1 below.

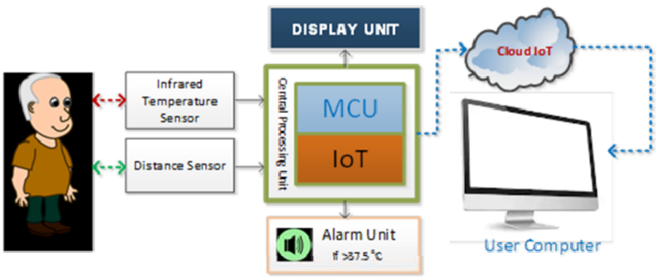

Fig.1. Structure of the proposed WA-BTSS using IoT platform

1. Sensing Mode

This part consists of two sensing devices: 1) non-contact infrared temperature sensor and 2) ultrasonic sensor. Both have their characteristics, which are described in the following subsections.

1.1 Non-contact infrared temperature sensor

Each body always with a temperature above absolute zero (-273, 15 ^{o}C = 0 Kelvin) emits electromagnetic radiation from its surface, proportional to its intrinsic temperature. Intrinsic radiation is infrared radiation, which can be measured a body's temperature. This type of radiation can penetrate the atmosphere [2]. This work non-contact infrared sensor GY-MLX90614-DCI long-distance infrared temperature sensor module [3]. It is a non-contact infrared thermometer with medical accuracy to measure temperature from 20 cm up to 50 cm. This model is the medical accuracy version, which needs unique code and power supply dependency compensation. It works with NodeMCU-ESP8266, which can communicate through the I2C interface with 3.3 V power from the Arduino board, and the voltage and compensated temperature will be read.

1.2 Ultrasonic sensor

The Reflective Ultrasonic Sensor sends ultrasonic waves from an emitter toward a sensing object, then receives the reflected waves with a detector. The sensor uses the resulting information to determine an item's presence or measure the distance to the thing. This sensor determines the sensor's reach to an object based on the time required from when the ultrasonic waves are sent until they are received using sound speed. Figure 1 applies an ultrasonic as a distance sensor to detect a human who comes to scan his body temperature at the determined position. The body temperature detector prepares to measure the temperature after receiving information that someone has stood at the designated location. Then, the operation of the microcontroller unit begins.

2. Embedded Microcontroller-WiFi Chip

This section describes the programming of embedded infrared sensors and microcontroller units. In this prototype, the NodeMCU-ESP8266 is adopted because it is a low-cost open-source IoT platform. The NodeMCU-ESP8266 development board comes with the ESP-12E module containing the ESP8266 chip having Tensilica Xtensa 32-bit LX106 RISC microcontroller. This microcontroller supports RTOS and operates at 80 MHz to 160 MHz adjustable clock frequency. NodeMCU has 128 KB RAM and 4MB of flash memory to store data and programs. It has high processing power with in-built WiFi/Bluetooth and deep sleep operating features [5].

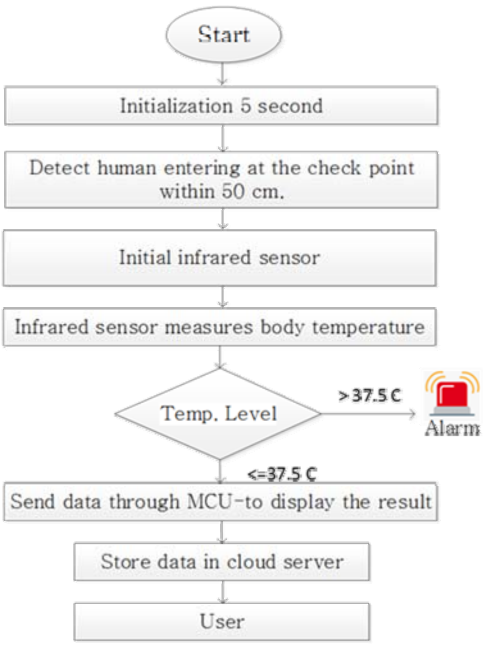

Fig.2. Flowchart of the proposed WA-BTSS

Figure 2 presents the proposed embedded WA-BTSS work procedure, which uses a non-contact infrared sensor. Whenever a man stands at the specified position, a man will be detected by the ultrasonic sensor. Then, the WA-BTSS gets ready to process within 5 seconds for acknowledging the central processing unit (CPU) to activate the non-contact infrared sensor, which is the primary function for measuring body temperature for people passing through at that place. The detection distance is about 50 cm from the infrared sensor, which range is long detection with high accuracy for medical technique. In case the non-contact infrared sensor is higher than 37.5 ^{o}C, a buzzer will wear the warning signal. NodeMCU-ESP8266 is the central unit to safely communicate with cloud internet service; the information will be transferred to the cloud internet server. The tracked data will be observed whenever a user requires it—the actual hardware is shown in Figure 3.

Fig.3. Hardware components of WA-BTSS device

3. IoT Communication Network

The IoT based on networking is defined as the proposed development of the Internet in which everyday objects have network connectivity, allowing them to send and receive data. The most important thing here of WA-BTSS is connectivity among objects.

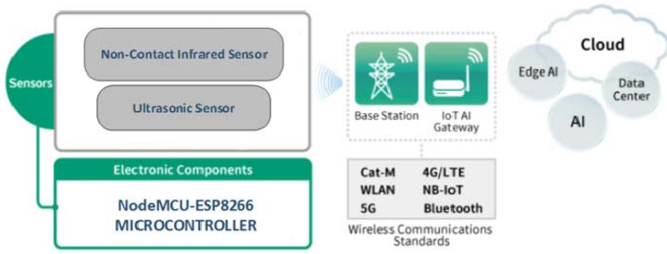

Fig.4. Presented IoT communication network on WA-BTSS system

The Embedded WA-BTSS with IoT platform provides numerous opportunities and facilities for implementing all the above sensors. However, the effective management of intelligent objects within the infrastructure remains challenging to achieve efficient communication between physical components while maintaining the cyber world's quality of service. The desired interoperability factor to hide the details of different technologies is fundamental to allow IoT developers not to be concerned with software services that are not directly relevant to the specific IoT application. This ability is offered by the middleware [6]. The middleware is considered to apply in being an ideal fit with IoT application development since it simplifies the establishment of new applications and services in complex IoT distributed infrastructures with numerous heterogeneous devices [7]. Namely, IoT middleware allows developers and users to experiment on IoT devices.

On the other hand, a cloud-based IoT middleware enables users to quickly interpret the data they have collected from the proposed WA-BTSS from an infrared sensor. However, the type and number of IoT devices that can be experimented with are limited. Thus, more in an actor-based IoT middleware, developers should provide different kinds of IoT device applications scattered around the network to experience the IoT's plug-and-play capabilities.

Experimental Results and Discussions

The proposed WA-BTSS using non-contact infrared and transmitting data via the IoT network creates an assistant monitoring medical device. This section mentions the understanding of accuracy and precision for the proposed WA-BTSS device. In most applications, accuracy is one of the more critical specifications that a product needs to meet. However, accuracy is also one of the more, if not the most, confusing parameters for any contribution, including WA-BTSS. Thus, this application is enormously used in the COVID-19 situation to provide insight into the numerous confusion sources. Hence, accuracy and precision are frequently used interchangeably, especially in promotional literature for non-contact infrared sensor products. Figure 4 shows the statistical distribution for precision versus proximity to an actual, target, or reference value for accuracy. A more precise sensor has a narrower distribution, and a more accurate sensor is closer to the real deal. Alternatively, the precision and accuracy can increase or decrease independently [8].

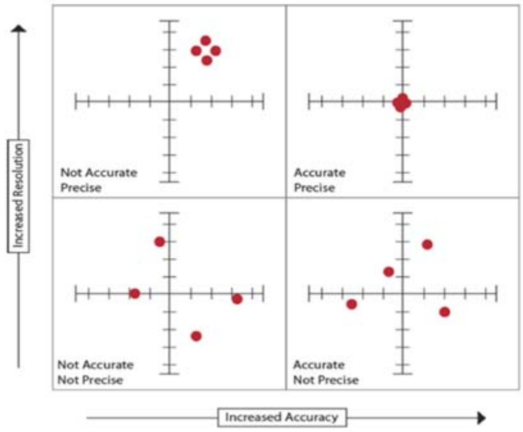

Fig.5. Presented IoT communication network on WA-BTSS system

Body Temperature Test

No.	Date/Time	Sensor	Standard
1	8/10/2020 18:17:00	36.7	36.9
2	8/10/2020 18:17:00	36.9	37.0
3	8/10/2020 18:17:00	36.9	36.9
4	8/10/2020 18:17:00	36.9	37.0
5	8/10/2020 18:17:00	36.8	36.9
6	8/10/2020 18:17:00	36.7	36.9
7	8/10/2020 18:17:00	36.9	36.9
8	8/10/2020 18:17:00	37.0	36.9
9	8/10/2020 18:17:00	36.9	36.9
10	8/10/2020 18:17:00	36.9	36.9
11	8/29/2020, 18:39:00	36.6	36.6
12	8/29/2020, 18:40:01	36.6	36.7
13	8/29/2020, 18:42:02	36.5	36.7
14	8/29/2020, 18:43:03	36.6	36.8
15	8/29/2020, 18:45:04	36.7	36.7

Fig.6. Experimental results from cloud server

The experimental results of measuring the body temperature using WA-BTSS presented as a screenshot in Figure 6 below.

Figure 6 details the information obtained from the WA-BTSS device that tracks body temperature wirelessly. The report consists of 1) number of lists 2) date 3) time 4) temperature (^{o}C) test from the proposed device and 5) temperature test of standard based on the model Bioland #E122. The data tested was collected for 60 samplings from the same wrist; the temperature average of the proposed model is 36.82 ^{o}C, while the referenced model's temperature average is 36.79 ^{o}C, according to Figure 7.

Group Statistics

	Types	N	Mean	Std. Deviation	Std. Error Mean
Sensor	1	60	36.82	.429	.055
	2	60	36.79	.183	.024

Fig.7. The results test between the proposed device and the standard device using independent sample *t*-Test

The Independent Sample t-Test compares the means of two independent groups to determine whether there is statistical evidence that the associated sampling test means are significantly different. Thus, the Independent Samples t-Test is a parametric test. The Independent t-Test is the observed mean difference ratio over the difference expected due to sampling error [9].

(1) $$t = (M1\text{-}M2)/S_{(m1\text{-}m2)}$$

The distribution of the difference of the sample's means would follow a t distribution. However, it should be noted that the two representatives of the temperature test from the proposed body temperature device and standard one display a normal distribution and have an equal variance because they are independently extracted from an identical population that has a normal distribution. Comparing the proposed body temperature device and standard type-based Bioland #E122 model is a significant value of .659. Namely, there were no differences in the performance differences between the two devices. The test result from the statistical program proved, as shown in Figure 8.

Independent Samples Test

		Levene's Test for Equality of Variances				
		F	Sig.	t	df	Sig. (2-tailed)
Sensor	Equal variances assumed	45.711	.000	.443	118	.659
	Equal variances not assumed			.443	79.665	.659

Fig.8. The performance test of both devices using Independent Sample *t*-Test

Figure 8 shows the analysis of both device's performance in terms of body temperature detection. The proposed WA-BTSS and standard device results under Thai Industrial Stand (TIS) are analyzed using Independent Sample t-Test by Statistic Package for the Social Sciences (SPSS). This statistic helps compare the performance of two sets of data obtained (dependent samples) [10].

Moreover, both performances are also evaluated using reliability statistics to verify the item's accuracy. Once the accuracy performance of item contribution is thoughtfully considered, the data can be used to estimate essential properties of the prototype's effectiveness, standard deviation, failure rate, reliability (at a fixed time t)

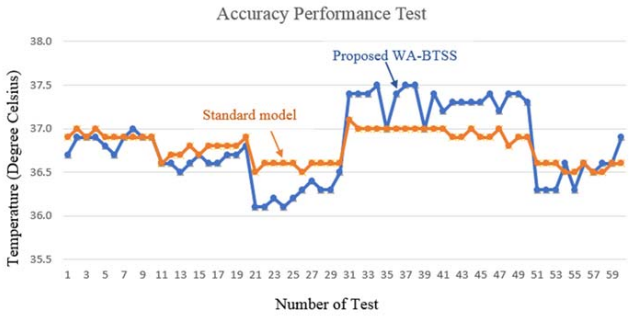

Fig.9. The performance test of both devices using Independent Sample t-Test

The individual test on body temperature devices of the proposed WA-BTSS and Bioland #E122 model is plotted, as shown in Figure 9. In order to verify the reliability of the obtained results from the proposed WA-BTSS prototype based on an embedded IoT platform. Thus, the reliability statistics result is obtained according to Figure 9.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.752	.911	2

Fig.10. The performance test of both devices using Independent Sample t-Test

Figure 10 shows the reliability statistics results from the SPSS program, which is usually an absolute number ranging from .00 to 1.00. A value of 1.00 indicates perfect consistency; a value of .00 indicates a complete lack of consistency [11]. Thus, the obtained result has a Cronbach's Alpha of .752, and it can be summarized that the proposed WA-BTSS performance in terms of accuracy test is positively consistent with the standard model (Bioland #E122).

Conclusion

According to COVID-19, the pandemic is an unprecedented health crisis on a global scale. Since early 2020, it has put tremendous strain on healthcare systems, disrupted economics, and halted large parts of social life in many countries worldwide. Therefore, the proposed WA-BTSS is helpful for the COVID-19 era because it can track body temperature wirelessly. The data will be uploaded into the cloud server IoT platforms as the most significant IoT ecosystem component. The proposed IoT-body temperature device permits connecting to other IoT devices and applications to pass on information using standard internet protocols. The data is stored in the internet cloud system; users can download the file to observe and analyze the obtained results. All of these purposes are to apply the proposed IoT technology appropriately to prevent epidemics and appropriate surveillance.

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