Contactless Body Temperature Monitoring of In-Patient Department (IPD) Using 2.4 GHz Microwave Frequency via the Internet of Things (IoT) Network

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Abstract

Since the COVID-19 situation keeps going on started from 2019. Many solutions are to against the spreading of coronavirus disease. In this work, the contactless body temperature monitoring (CBTM) of the in-patient department (IPD) is applied using a 2.4 GHz microwave band via the Internet of Things (IoT) network. The specified infrared body temperature on the MLX90614 DCI used for the medical field was selected to embed the IoT-CBTM for IPD using the IoT platform because the MLX90614 is an accurate sensor that matches to use for medical promotion. In this study, the proposed embedded IoT-CBTM has tested the accuracy compared with the manual body temperature checking device under the Thai Industrial Standard Institute (TISI). The results found that the proposed wireless IoT-CBTM prototype achieved a reliability value of 48.7 %, nearly to the expected value, with positive correlations between devices at .322*. The information data will be transferred to store at cloud internet according to the time set every hour. The intelligent applications used for receiving data are Google Sheet and line application on smart devices.

Keywords: COVID-19, CBTM, IPD, TISI

1. Introduction

IoT can provide substantial value across the entire life sciences value chain, from research and development digitalization to enhancing the patient experience. This remote technology based on IoT platform is especially true in Coronavirus-19 disease, directly impacting public health measures on service medical in social sectors. This research article proposes the contactless body temperature monitoring of the in-patient department (IPD) using the internet of medical promotion. IoT has started to find broader applications in the field of medical material management visualization [1]. The proposed IoT-CBTM used for the in-patient department assists in avoiding public health problems by aiding in medical treatment. The device can track the body temperature of IPD automatically using a wireless infrared sensor embedded IoT-Microcontroller module. This solution increases medical treatment quality while the seriously COVID-19 disease situation regarding the ward's routine activities measures the vital signs, such as heart rate, blood pressure, and body temperature. Based on these data, the medical officer can remotely observe the patient's monitoring process. This paper focuses on a remote body temperature monitoring system, which proposes to keep up with emergencies during COVID time. The proposed item works on microwave frequency which is a form of electromagnetic radiation, and it operates frequencies ranging from 300 MHz to 300 GHz [2]

The infrared thermometer sensor is adopted to measure body temperature on the forehead. Measuring a person's temperature can be done in several ways, and in this work, the infrared thermometer sensor MLX90614 DCI infrared sensor was adopted to measure a person's surface temperature with non-contact on the forehead. Long-distance measurement of a person's body temperature may be used to reduce cross-contamination risk and minimize the risk of spreading Coronavirus disease. While typically -70 ℃ - 380 ℃, but in consideration of body temperature period is about 37.0 ℃, which is the average temperature, some studies have shown that normal temperature can be within a wide range, from 36.1 ℃ to 37.2 ℃. Therefore, this proposed prototype proposes understanding the benefits, limitations, and proper use of these contactless body temperatures. The improper use of them may lead to inaccurate temperature measurements. Thus, the accuracy issue was solved to get more reliability of the prototype according to the discussion section. This paper has organized as the following sections: Related works are mentioned the literature reviews of current and previous areas; following with the proposed IoT-Body temperature monitoring, which is consisted of 1) Proposed framework of body temperature monitoring of IPD 2) Embedded medical body temperature sensor-IoT controller 3) Proposed programming design. The following Section presents the experimental results and discussions. Lastly are the conclusions.

2. Related Works

The application of remote health monitoring is still new in Thailand and many other countries [3]. Some papers researched health monitoring; Sumit M. and et al. innovated wearable sensors for remote health monitoring [4]. They have researched the remote health monitoring systems on physiological parameters and activity monitoring systems—moreover, Tamilselvi. V and et al. [5] have studied the IoT-based health monitoring system. Their proposed system was specially designed for actual-time monitoring of the health parameters of the coma sufferers. The technologies used in this system were GSM and IoT to recognize the patient's condition. The parameters studied were temperature, heartbeat, eye blink, and peripheral capillary oxygen saturation (SPOS). Those parameters were detected using sensors for fetching the patient's body temperature, coronary heart rate, eye movement, and oxygen saturation percentage. Similarly, N. Saowakhon and et al. also studied the development of IoT heartbeat and body temperature monitoring systems for community health volunteers [6]. The device uses Arduino that connects to the heartbeat and temperature sensors with the data connection to the ThingSpeak IoT platform in real-time through an internet network.

Many works were researched the health parameters of a patient using remote monitoring. Similarly, M. Goncalo and P. Rui have studied a non-contact infrared temperature acquisition system based on the internet of things for laboratory activities monitoring. The temperature monitoring inside the building was the proposition that needs to solve the problem. The iRT non-contact temperature sensor was used for a data acquisition system based on IoT, which was designed to be a cost-effective solution. Their work was similar to the proposed contactless body temperature monitoring of IPD via an IoT network because the iRT non-contact infrared was used. However, the proposed work uses non-contact infrared temperature sensor MLX90614-DCI with a long distance from 1 cm up to 50 cm supported medical tool promotion during COVID-19 spreading because it can be safe the medical doctor and medical personnel as well.

3. Proposed IoT-Body Temperature Monitoring System

The contactless body temperature monitoring of IPD via the IoT network proposes to use in a hospital during the COVID-19 situation. The concept was not complicated using a non-contact infrared temperature sensor embedded with an ESP32-IoT module. The information involved is detailed in the following items.

3.1 Proposed Framework of Body Temperature Monitoring of IPD

The related studies of "Contactless body temperature monitoring of IPD via the IoT network" were reviewed. This Section presents the overall system that designed and developed an embedded system using an infrared temperature sensor that works with an IoT-Wifi controller on the NodeMCU ESP32 board. The detected data will be transferred to users via the internet network, and it will be stored on a cloud internet system. The proposed system is presented in Figure 1 below.

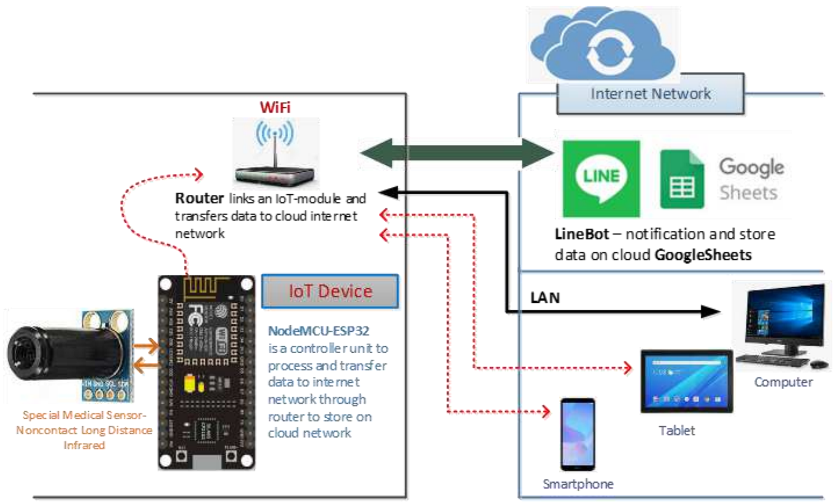
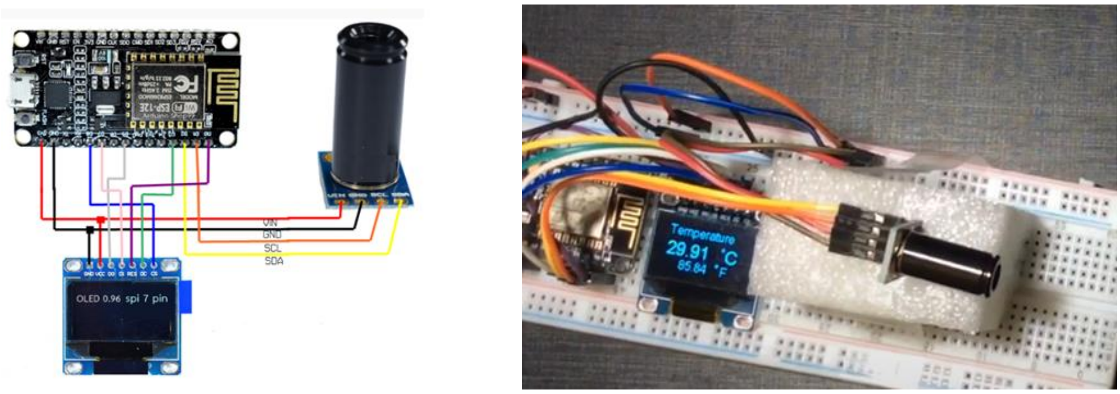


Figure 1. Proposed IoT-CBTM system

The system was designed to embed the software programming according to the user's requirements. The monitoring module for IPD using IoT network uses innovative embedded medical sensor and smart monitor applied in conjunction with the IoT technology. The information can be viewed at any time, and it alerts when something goes wrong. The information data will be stored on the cloud network, which is a storage system on the internet). The highlight of this innovation is storing data in real-time, and it can be browsed through the online internet system with the notification system. Therefore, this prototype improves hospital management and patient care because it can reduce infection risk from working in a risky area.

3.2 Embedded Medical Body Temperature Sensor with IoT-Controller

This Section presents on IoT-Microcontroller embedded DCI90614ESP infrared. IoT-Microcontroller adopted to use is ESP32, which is a single 2.4 GHz Wifi and Bluetooth combo chip [7]. It is designed to achieve the best TSMC ultra-low power consumption and RF performance with robustness, versatility, and reliability in a wide variety of applications and power scenarios. Meanwhile, the non-contact infrared body temperature for IPD with above absolute zero (-273, 15 oC = 0 Kelvin) emits electromagnetic radiation from its source, proportional to its intrinsic temperature. The medical sensor module can communicate with it through its I2C interface, high precision non-contact temperature measurements. It is also a thermal comfort sensor for the mobile air conditioning control system, which matches the healthcare section [8, 9].



(a) Schematic circuit

(b) Actual test circuit on breadboard

Figure 2. Schematic circuit of CBTM device for IPD based on individual design

Figure 2, aside from Wifi-Controller ESP32 and the long-distance medical sensor for detecting a maximum of 50 cm. An organic light-emitting diode (OLED) was adopted to create digital displays in the temperature monitoring device. Blue OLED is emitted in this type, and it generates a brighter light. Also, it is more uniform and more energy-efficient than regular fluorescent lights [10], with in-built antenna switches, RF balun, power amplifier, low-noise receive amplifier, filters, and power management modules. Moreover, it added versatility in the applications with minimal print circuit board requirements.

3.3 Proposed Programming Design

This Section describes the programming design of a non-contact infrared sensor with an IoT-ESP32 controller device. The functions of this device were designed according to the user's requirements. The sequences of the prototype's working are shown in the following steps according to the flowchart in Figure 3.

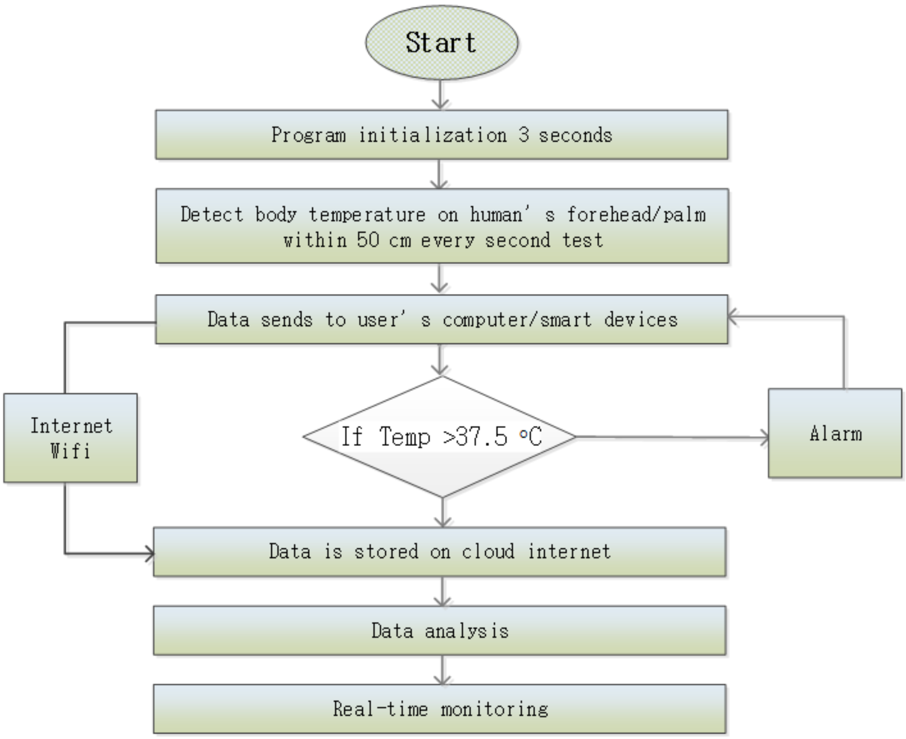


Figure 3. Flowchart of contactless body temperature monitoring system based-IoT network

The contactless body temperature monitoring-based IoT network platform provides the structure. The prototype module was designed to specified use for hospitalized patients who usually needed to observe their body temperature regularly. The embedded program can detect the human's body temperature according to the user's design, which usually every 4-6 hours, but in the design, the temperature is monitored every 1 hour. The detected temperature will be verified at the temperature reference of 37.5 ℃. Namely, when the monitored data is lower than the reference value, it will be sent to the cloud internet for further analysis. In contrast, when the monitored data is equal to or higher than 27.5 ℃, the alarm function will notify the user and the user's computer.
This function design makes it much easy for the user in a medical ward. The prototype can reduce and close contact with vulnerable patients and save time for regularly measuring temperature. The prototype also supports the patient to rest due to reducing interference from the temperature measurement every 4 hours.

4. Experimental Results and Discussions

This Section presents the experimental results and discussions on contactless body temperature monitoring of PID through the IoT platform. The proposed device using a microwave frequency band of 2.4 GHz internet onboard for data transmission. Figure 4 presents the monitoring results of two infrared temperature sensors. The first device (sensor#1) is the typical body temperature under the Thai Industrial Standards Institute (TISI), compared with the proposed device (IoT-Sensor#2) is embedded infrared sensor into the microcontroller-IoT device. Both devices are tested based on the same conditions using the same Person's temperature at the nearest time at the distance of 5 cm.

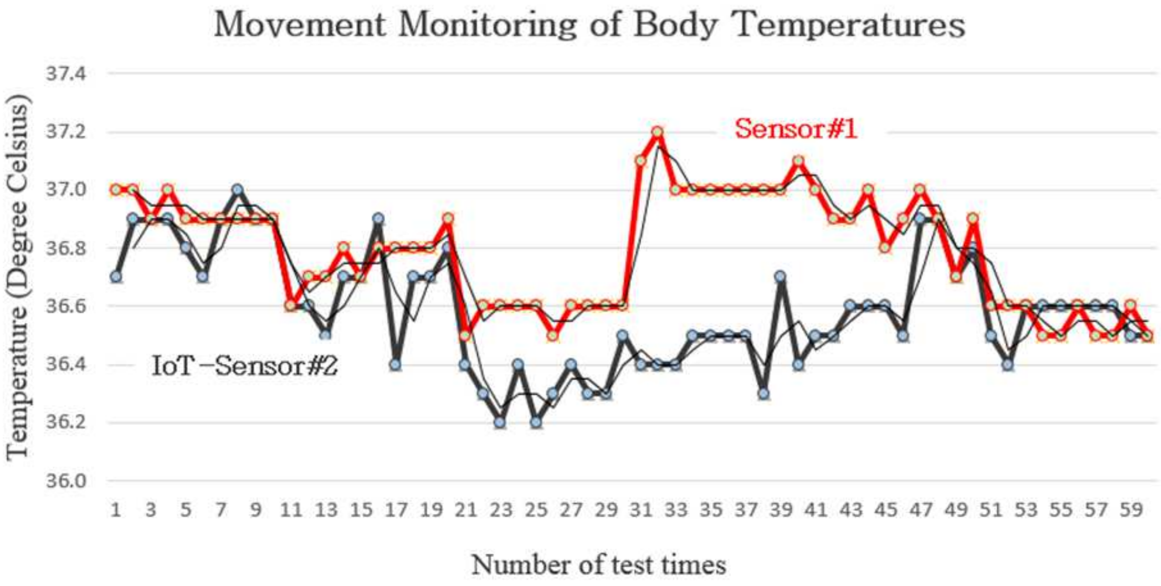


Figure 4. The comparison of body temperature movement monitoring of both sensors test

The results showed that both devices are the proposed embedded infrared body temperature device, which has an average value of 36.59 ℃, and the standard device has an average value of 36.79 ℃, which are different of temperatures value of 0.56.

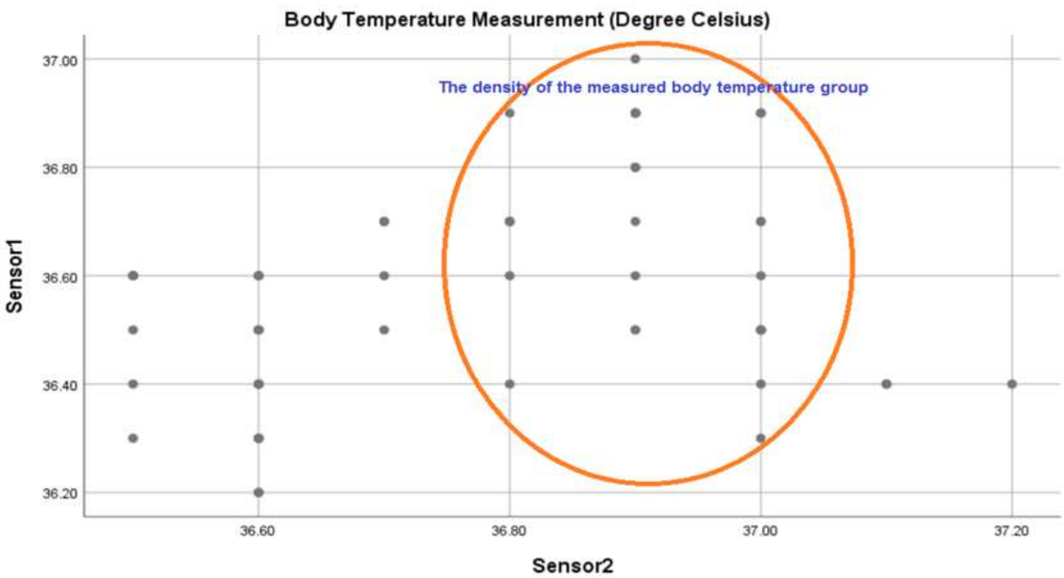


Figure 5. The density group of the measured body temperature test

Figure 5 presents the density group of both devices' measured body temperature test between the proposed wireless IoT-body temperature device and the standard device, which are dense at about 36.80 ℃ to 37.00 ℃. According to the plotted results of both sensors in Figure 6, they are compared of the proposed IoT-wireless infrared body temperature and infrared body temperature under TISI Standard. The results found that the correlations of both devices are related at .322*. The statistical results have shown that the two devices were related to each other positively weak correlation. In contrast, both devices' results can be summarized as work independent way, but according to the different values of body temperature testing for 60 times, it is about 0.56 only. The results depend on the interference factors, such as distancing a test and other human factor stability.

Correlations

		Sensor1	Sensor2
Sensor1	Pearson Correlation	1	.322*
	Sig. (2-tailed)		.012
	Sum of Squares and Cross-products	2.409	.745
	Covariance	.041	.013
	N	60	60
Sensor2	Pearson Correlation	.322*	1
	Sig. (2-tailed)	.012	
	Sum of Squares and Cross-products	.745	2.217
	Covariance	.013	.038
	N	60	60

*. Correlation is significant at the 0.05 level (2-tailed).

Figure 6. First correlation test of both devices

Correlation coefficients are used to measure how strong a relationship between variables. There are several types of the correlation coefficient, but the most popular is Pearson's. Namely, Person's correlation is a correlation coefficient commonly used in linear regression [11, 12].

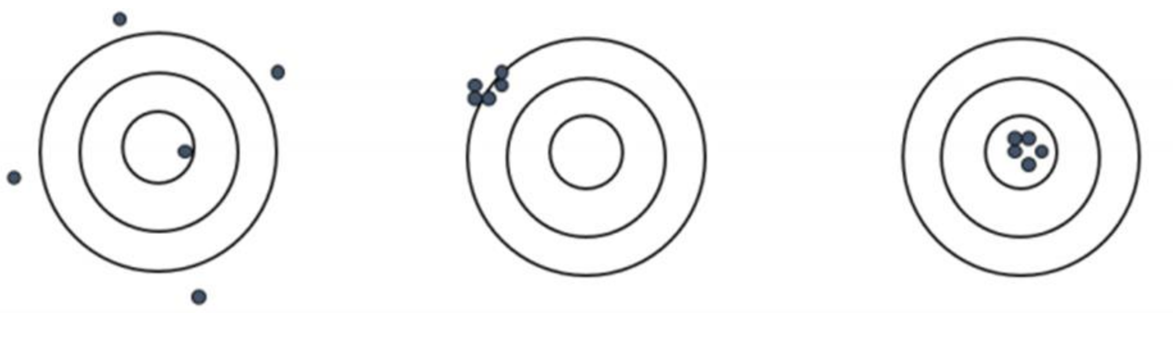
Therefore, the proposed device has verified the reliability of both devices using statistical proof. It was found that the wireless IoT-body temperature monitoring device implemented has a reliability rating of almost 50 %. In case it needs to up the value higher, it must be calibrated for few times.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.487	.487	2

Figure 7. The reliability statistics results referring the standard TISI device.

Figure 7 analyzes the reliability test of the proposed IoT-wireless CBTM. Reliability theory is essentially applying probability theory to the modeling of failures and the prediction of success probability.



(a) Low reliability (b) High reliability/Low validity (c) High reliability/High validity

Figure 8. Testing a device's accuracy performance

This Section mentions some of the key points in the reliability of the proposed device, which these parameters are the reliability and validity are the two most important properties that test scores can have. Reliability tells about consistently the test scores measure body temperature. On the other hand, the validity tells whether the test scores measure the correct values for a particular use of the test. This research's highlight is about accuracy tests of several measuring for body's temperature, which focus on forehead within the same conditions to achieve the calibration as close as possible.

5. Conclusions

The proposed contactless body temperature monitoring of IPD via the IoT platform is a green technology using powerful wifi and Bluetooth modules that target a wide variety of IoT for medical promotion applications ranging from low-power sensor networks to the most demanding tasks. The proposed device was helpful to reduce the contact, proximity between patients and healthcare professionals. The information data is organized to send and record into the cloud database system, which is further easy to analyze and evaluate by a relevant expert. This proposed automatic body temperature monitoring system is a pilot project that improves and develops in various ways even more in the future.

Acknowledgment

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Figures

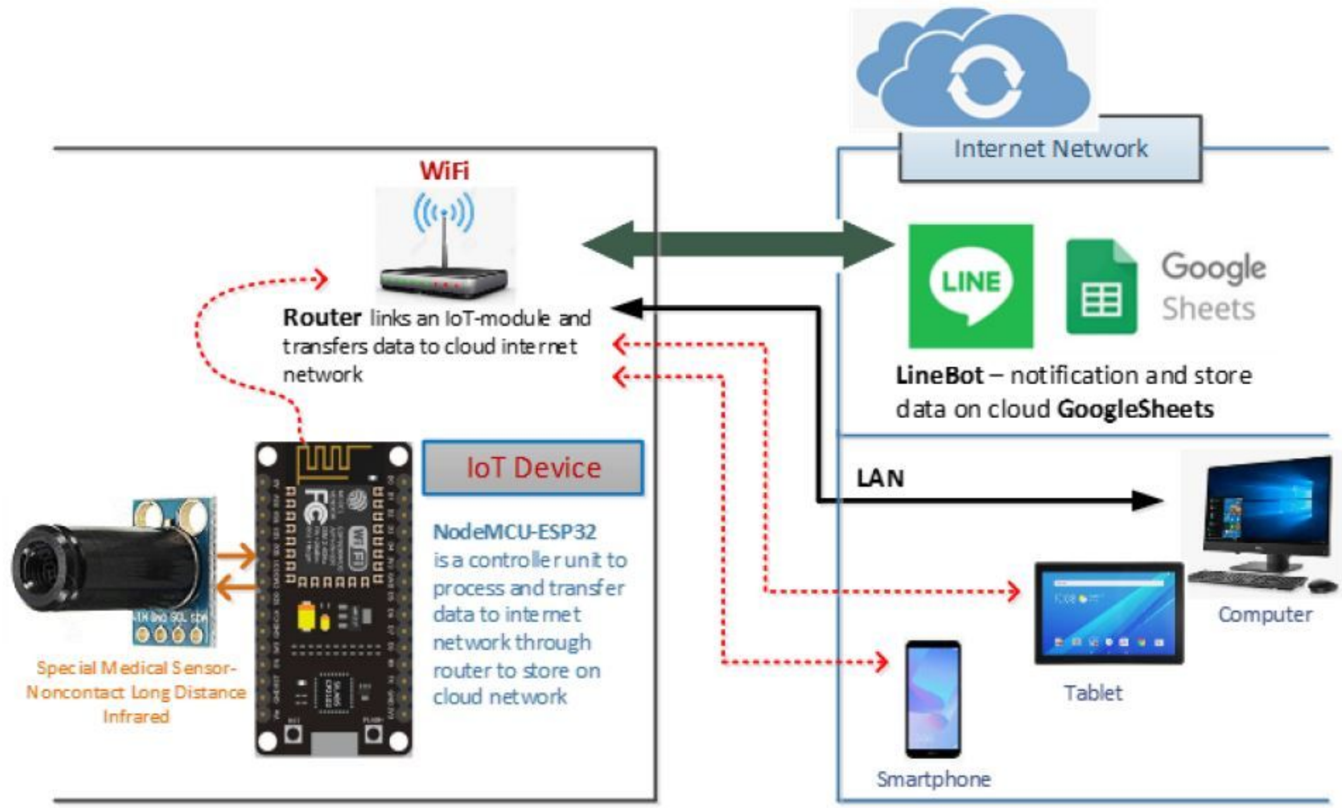

Figure 1

Proposed IoT-CBTM system

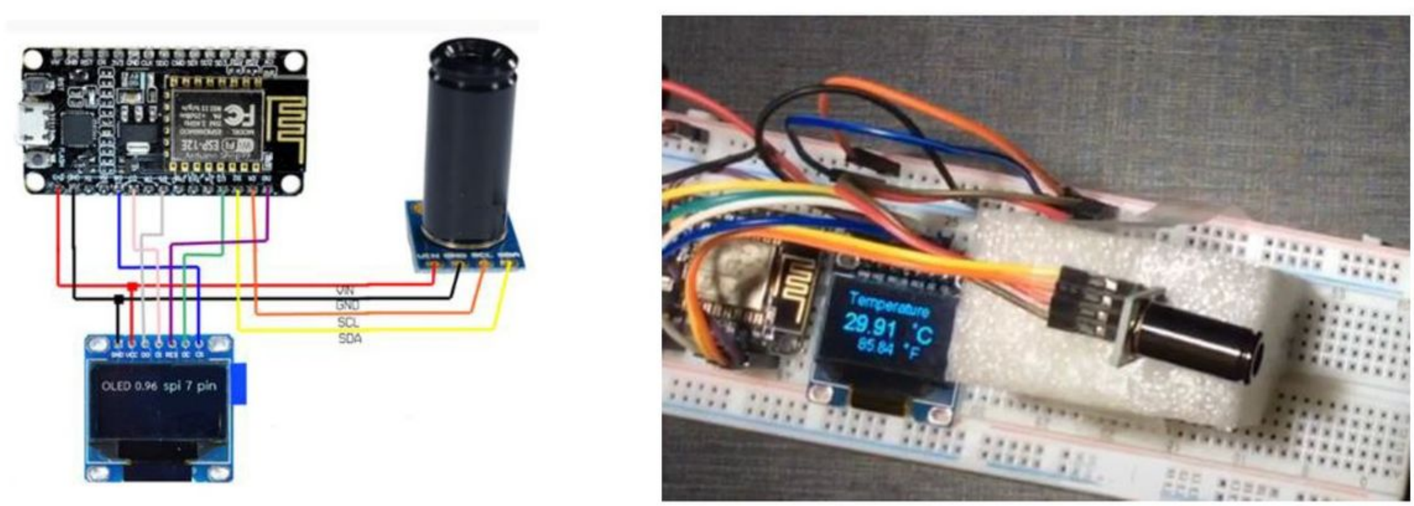

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Figure 2

Schematic circuit of CBTM device for IPD based on individual design

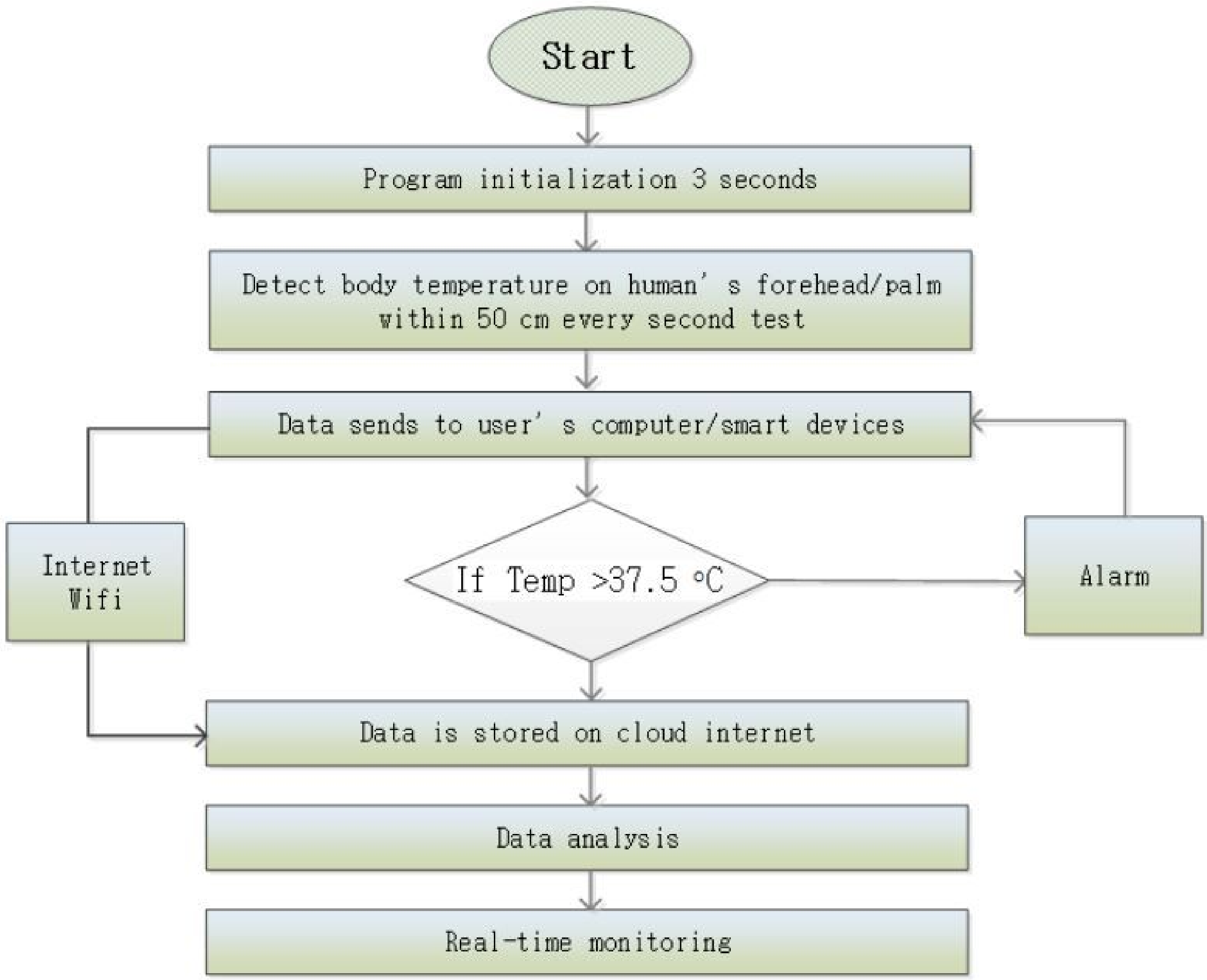

Figure 3

Flowchart of contactless body temperature monitoring system based-IoT network

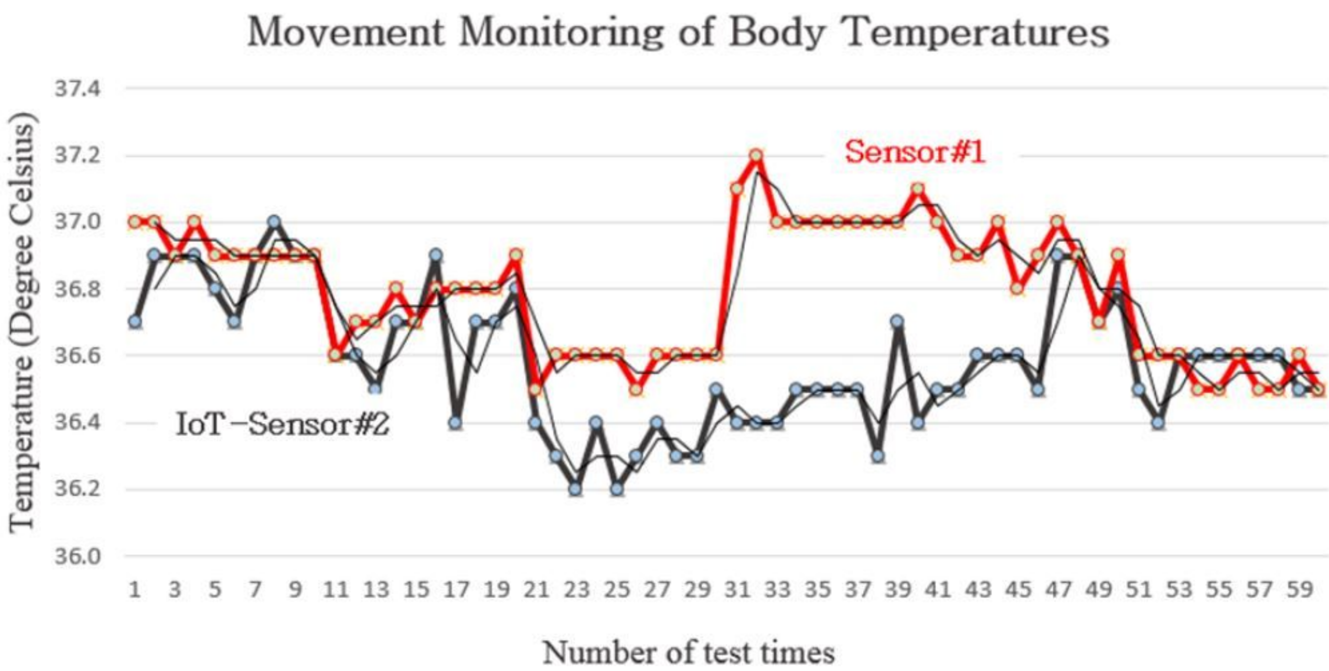

Figure 4

The comparison of body temperature movement monitoring of both sensors test

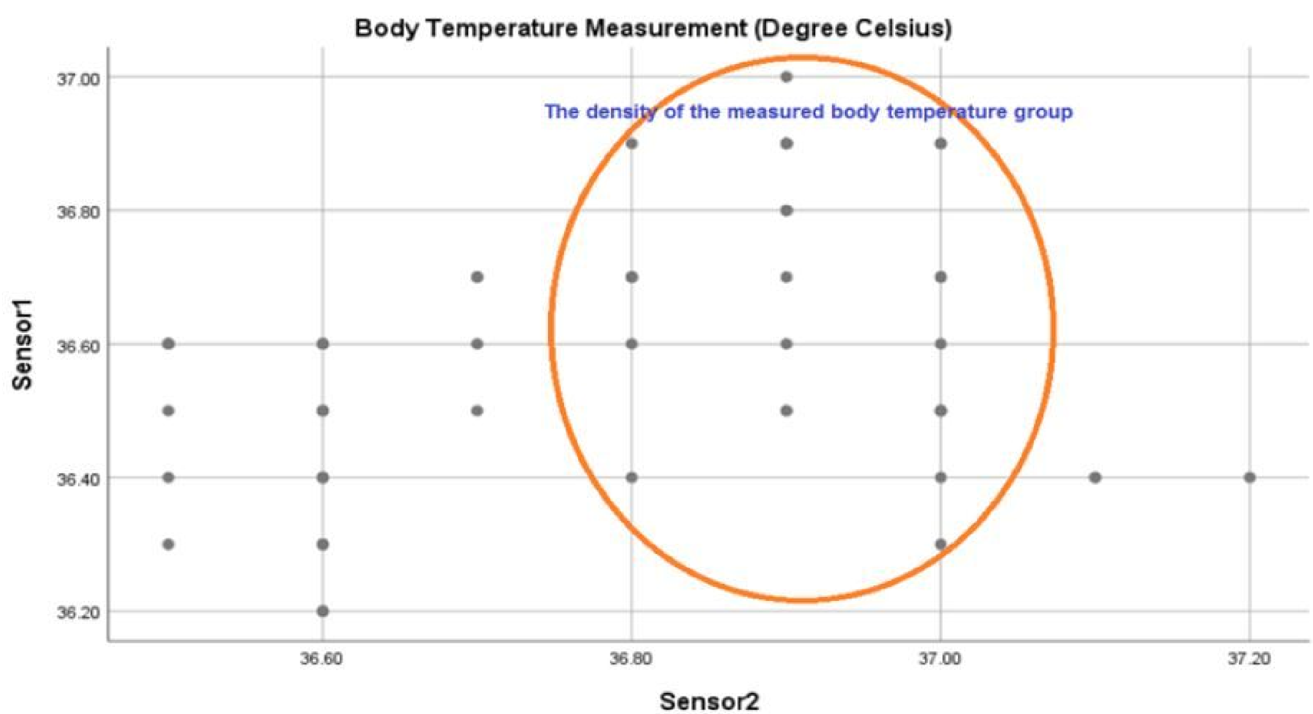

Figure 5

The density group of the measured body temperature test

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		Sensor1	Sensor2
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	Sum of Squares and Cross-products	2.409	.745
	Covariance	.041	.013
	N	60	60
Sensor2	Pearson Correlation	.322*	1
	Sig. (2-tailed)	.012	
	Sum of Squares and Cross-products	.745	2.217
	Covariance	.013	.038
	N	60	60

*. Correlation is significant at the 0.05 level (2-tailed).

Figure 6

First correlation test of both devices

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Figure 7

The reliability statistics results referring the standard TISI device.

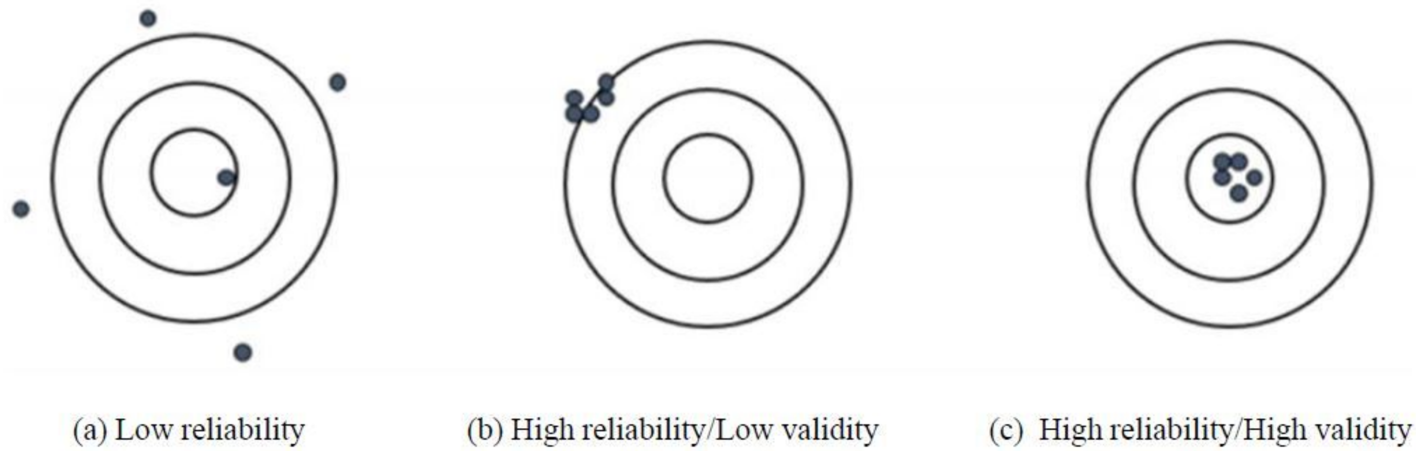

Figure 8

Testing a device's accuracy performance

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