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IoT-Based Health Monitoring and Tracking System for Self-Quarantine of Covid-19 Patients

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Abstract: As a result of the global spread of the COVID-19 pandemic, social isolation and quarantine are now globally mandated practices. From this perspective, implementing an Internet of Things (IoT)-based health monitoring and tracking system would be the most effective response to a pandemic. Therefore, this project aims to facilitate early diagnosis and treatment based on the Internet of Things (IoT) technology. A portable health monitoring and tracking system that can monitor basic health factors such as a person's body temperature, heart rate, and SPO2, as well as their location data, were constructed. Due to the widespread availability of the internet, the system may be remotely monitored at specified intervals using either the online or mobile application. The hardware-based system of the suggested technique employs an Espressif ESP32-WROOM-32 with temperature, SpO2, heart rate and GPS sensors, and the IoT-based method employs the ThingSpeak platform. The proposed system was tested and validated on 10 human subjects and yielded positive results. To verify the efficacy of the sensors, the measured data were compared to the commercial product. It showed approximately maximum relative error between the proposed and the commercial product reading in the measurement of a patient's body temperature, heart rate, and SPO2 were found to be 2.08%, 1.20%, and 0.69%, respectively. The collected data from the sensors are kept on the ThingSpeak platform at intervals ranging from one second to fifteen seconds. In addition, this project facilitates real-time data collection. A notification system will be triggered when there are any changes to the predetermined standard values of a patient's health, and then the IoT system will alert the clinician or doctor in line with the patient's conditions and location. Even if the patient is located in a remote location, a precise diagnosis of their present health is still feasible and limits the risk of disease transmission. In addition, the cloud platform offers data logging, making it easy to review prior collected data and enabling clinicians to diagnose and treat patient health issues promptly.

Keywords: Health Monitoring, Tracking, Internet of Things, ThingSpeak

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1. Introduction

The spread of coronavirus outbreaks has shocked the world for more than a year, with millions of confirmed cases worldwide, including in Malaysia [1]. As a result of the pandemic that has ravaged our country, some problems have arisen in our economy, work ethics, way of life, political system, and educational system [2]. Malaysia's Prime Minister, Ismail Sabri Yaakob, stated that the country will begin its transition from the COVID-19 pandemic to an endemic phase on Friday, April 1, 2022 [3], with 97 percent of the adult population receiving at least two doses of the vaccine. It's time for the country to learn to "live with the virus." However, recent COVID-19-related news indicates that Malaysia has decided on "COVID-19 SOP RELAXATION FROM 1 MAY 2022" [4] as shown in Figure 1. This means that each person will continue to face different problems and challenges in the future. After all, the loosening of SOP will make it easier for viruses to spread than before because people will no longer have to separate themselves from one another, and masks physically will no longer be required to be worn outside.

Figure 1: COVID-19 SOP Relaxation From 1 May 2022 [4]

Figure 1 shows the COVID-19 SOP relaxation that will be implemented starting May 1, 2022. As shown above, COVID-19 positives, by default, are required to be quarantined for 7 days. The COVID-19 Assessment Centre has been downgraded in its functionality by The Government of Malaysia since the country entered the endemic phase of the disease [5]. Each person must take responsibility for their actions and do self-quarantine at their locations to maintain their level of safety. The period spent in quarantine is lengthy, and symptoms can appear during this time [6]. Because at that time, anything might go wrong, it is necessary to have it monitored by the appropriate professional, such as a doctor.

Figure 2 shows that the total number of deaths caused by COVID-19 in Malaysia is about 35,712 as of June 12, 2022 About 21 % of the total deaths in Malaysia, which is 7,573, are brought in as brought-in dead cases (BID). In simple terms, "brought-in dead cases" means the patients died without undergoing any medical observation [8]. The number of brought-in dead cases can be reduced if the patients get early detection of symptoms by the doctor or any related person.

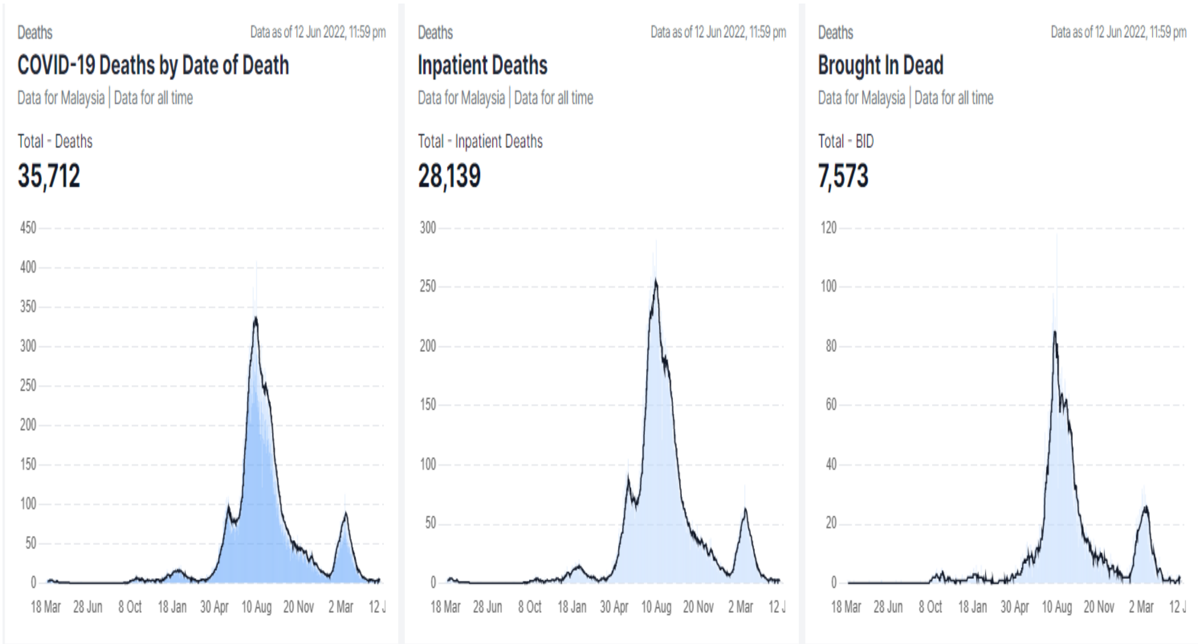


Figure 2: Data of Deaths Caused by COVID-19 in Malaysia [7]

An existing home self-quarantine system for COVID-19 patients currently implemented in Malaysia is inefficient and unreliable because the patients are not monitored on a real-time basis on their health conditions. The patients must fill out the health assessment form in the *MySejahtera* apps. Even the patients must have a few medical types of equipment such as an oximeter, thermometer and blood pressure monitor. Using an oximeter is crucial to monitor oxygen saturation levels as this COVID-19 attacks the human lung, which can cause lower oxygen levels in the body. Due to this increment of brought-in dead (BID) cases, there is a need for a solution to gain reliable continuous monitoring by the doctor or any related person. A solution for patients in Malaysia based on a health monitoring and tracking system can be monitored. In this case, the project develops an IoT-based health monitoring and tracking system that integrates sensors with a microcontroller (ESP32-WROOM-32) and then links to the IoT platform, which is ThingSpeak.

2. Materials and Methods

This portable system was built using the Espressif Systems ESP32-WROOM-32 MCU modules as the microcontroller, the MAX30102 as a high-sensitivity pulse oximeter and heart rate sensor, the MLX90614 as a non-contact temperature sensor, an OLED display as an output display device, and the ThingSpeak platform as an Internet of Things (IoT) platform. Figure 3 shows the construction of this system. The input data of basic health parameters like SpO2, heart rate, and temperature that come from MAX30102 and MLX90614 sensors as well as the GPS location data like latitude and longitude that come from the NEO-6M GPS module are going to be processed by the ESP32-WROOM-32 and published to the cloud. The processed data is presented on an OLED display as an output for the device, and it is uploaded wirelessly to the ThingSpeak platform for monitoring and tracking. The Pushover application is a third-party mobile application that has been linked to the ThingSpeak platform. When the system triggers the events that have been specified in the ThingSpeak platform, such as a high temperature or low SpO2, a notification is sent to the smartphone of the authorizer through the Pushover application. This means that the patient can get the right care as soon as it is available.

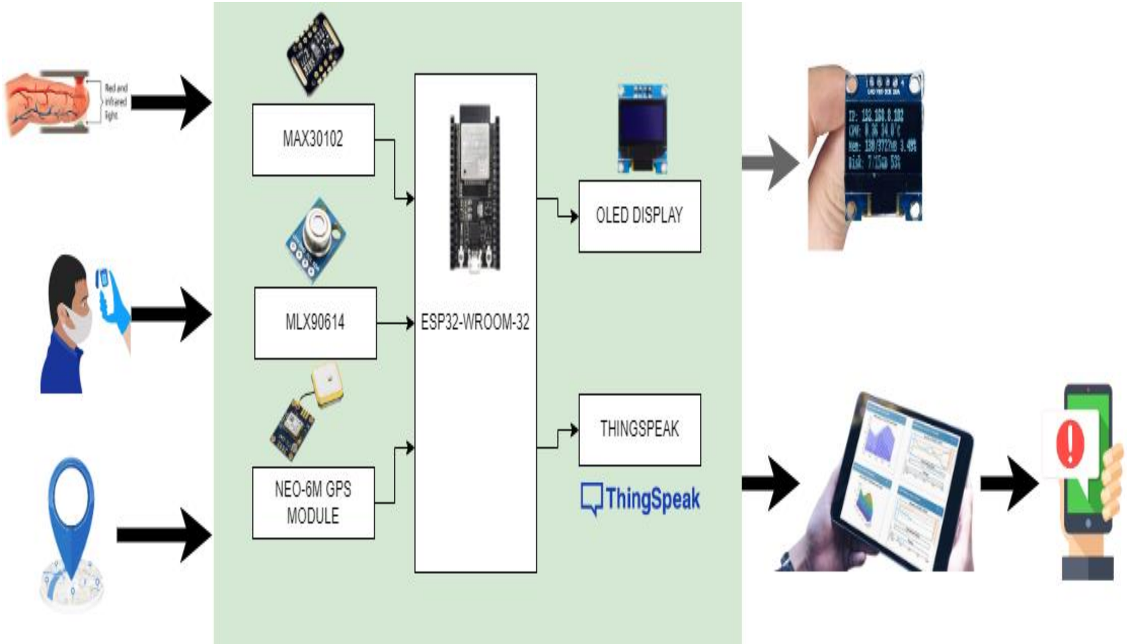


Figure 3: Block Diagram of the System

2.1 Flow Chart

Figure 4 presents the flow chart that describes how the system works. The system will now begin the process of initialising the connection between the microcontroller and the input/output devices, as well as the connection with the platform for the Internet of Things. This will take place irrespective of whether or not the component and platform are prepared to be put into use. There are two primary functions: the first is health monitoring, which involves the measurement of fundamental health parameters like SpO2 and heart rate, and the second is tracking monitoring, which involves the measurement of GPS data locations, which are latitude and longitude. Each of these capabilities will be illustrated in further depth in the following Figure 4. The basic health parameters data will be automatically published to the Internet of Things platform while the GPS location data needs to be manually published only if the data location is available by pressing the button. The notification system has been designed using the ThingSpeak platform by creating the events and linking them with the third-party mobile application, which is Pushover Apps, to trigger and send notifications. Figure 5 illustrates the flow chart that describes how the events notification system works.

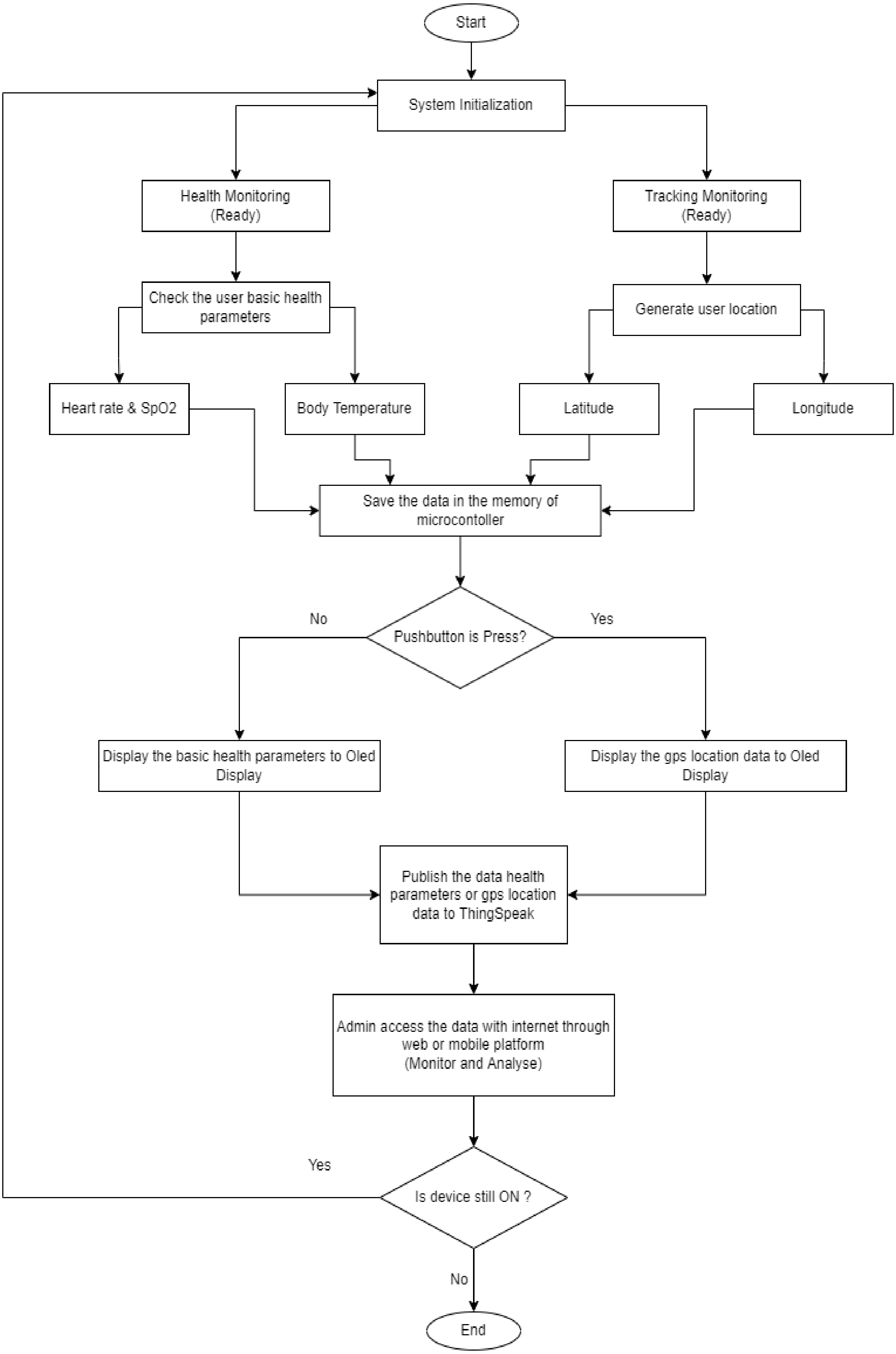


Figure 4: Flow Chart of the System

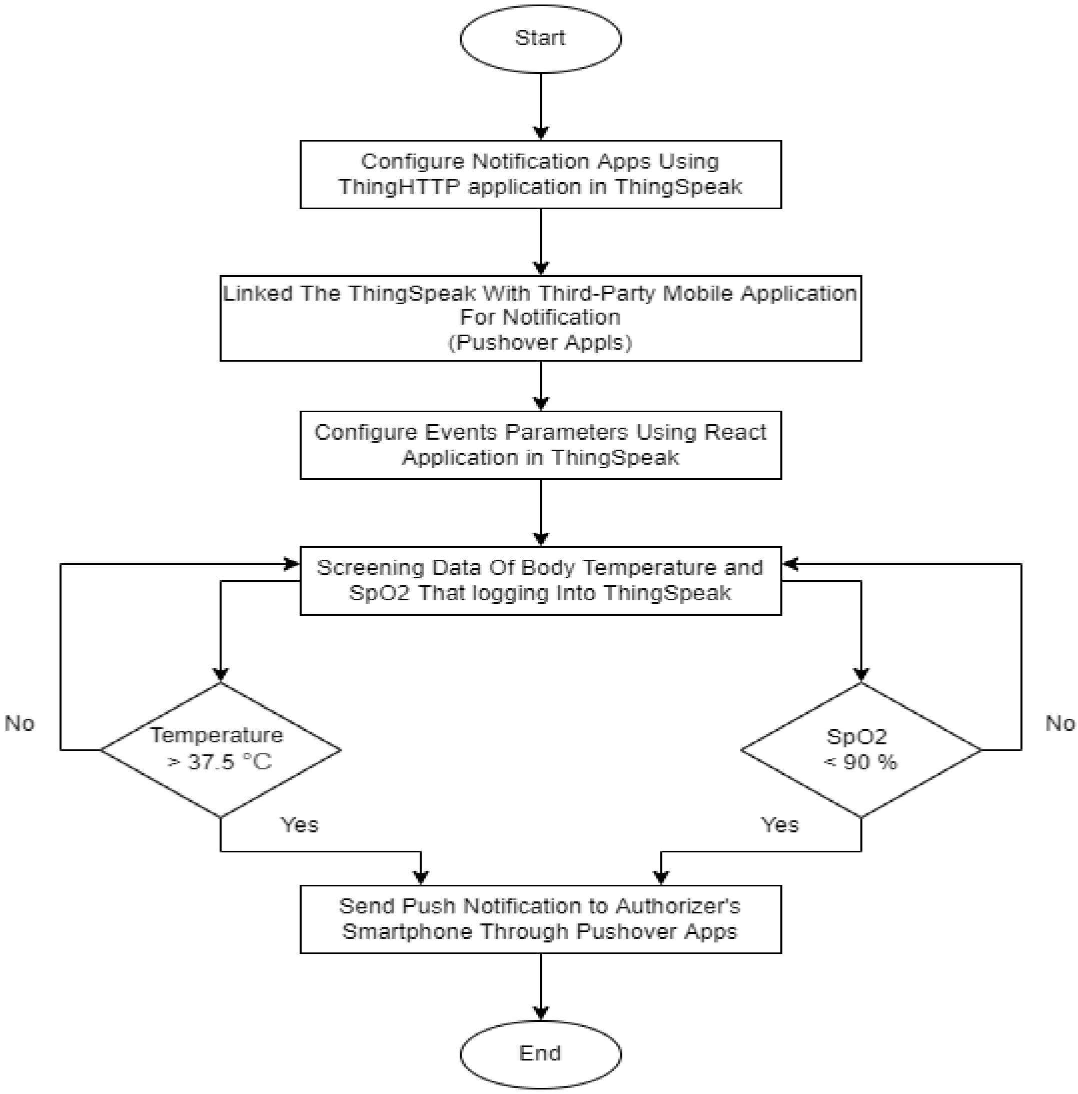


Figure 5: Flow Chart of The Events Notification Creation

2.2 An Existing Device for Testing and Calibration Purpose

Figure 6 and Figure 7 present an existing device, also known as commercial products, that has been used to compare with the proposed health monitoring and tracking system device, which is an existing pulse oximeter that has been used in testing and calibration for the level of heart rate and SpO2, while an existing infrared thermometer has been used in testing and calibration for the level of body temperature.

Figure 6: An Existing Pulse Oximeter

Figure 7: An Existing Infrared Thermometer

3. Results and Discussion

The findings shown in Table 1 and Table 2 are for the health monitoring system from ten subjects who are comparable in terms of age and gender but differ in terms of their weights and heights. The vital measurements of the subjects were tracked and compared to obtain the average readings with an existing pulse oximeter for the SpO2 and heart rate, while the temperatures of the subjects' bodies were compared to the readings from an existing infrared thermometer.

Table 1 shows the percentage error reading of heart rate and SpO2 between the proposed health monitoring and tracking system device and an existing pulse oximeter. As shown below, the largest value of error is about 1.20% of heart rate and about 0.69% of SpO2. From the results obtained, the proposed health monitoring and tracking system device is feasible to use because, in the "Guidelines for Testing and Calibrating Medical Devices" published by the Ministry of Health RI in 2001, the maximum limit in the pulse oximeter error tolerance is for a heart rate of 5% and SpO2 1% [9]. Besides, Table 2 shows the percentage error in reading body temperature between the proposed health monitoring and tracking system device and an existing body temperature scanner. As shown below, the largest value of error is 2.8%. Based on the results, the proposed health monitoring and tracking system are possible to use because the error is small compared to a commercial product that is already on the market.

Table 1: The average SpO2 and heart rate of 10 subjects after 3 data readings

	SpO2 (%)		% Of Error	Heart Rate (BPM)		% Of Error
	Device	Existing Device		Device	Existing Device	
Patient1	98	97.33	0.69	100.33	100	0.33
Patient2	99.33	99	0.33	85	84	1.19
Patient3	99	99	0	95.33	96.33	1.04
Patient4	98	97.66	0.35	97.33	96.33	1.04
Patient5	97.66	97.33	0.34	103	102.66	0.33
Patient6	97	97	0	99	99	0
Patient7	98.33	99	0.68	82	83	1.20
Patient8	99.66	99.66	0	84.66	84.66	0
Patient9	99	98.66	0.34	97.66	97.33	0.34
Patient10	98	97.66	0.35	105.66	106	0.32

Table 2: The average of body temperature 10 subjects after 3 data readings

	Body Temperature (°C)		% Of Error
	Device	Existing Device	
Patient1	36.52	36.73	0.57
Patient2	36.23	37	2.08
Patient3	36.51	37.03	1.40
Patient4	36.07	36.63	1.53
Patient5	36.92	36.76	0.44
Patient6	36.73	36.9	0.46
Patient7	36.89	36.97	0.22
Patient8	37.01	36.93	0.22
Patient9	36.23	37.00	2.08
Patient10	36.73	36.90	0.46

The findings shown in Table 3 are the latitude and longitude of GPS data location retrieved from the device for the tracking monitoring system from two locations of the subject. the accuracy of the generated location will be tested by manually locating the latitude and longitude using a mapping platform such as Google maps.

As shown in Figure 8 and Figure 9, the GPS data location that was retrieved from the GPS module of the device is entirely accurate since the pin location based on the GPS data and the exact location are approximately close to each other, which means that someone can easily find the accurate location using that GPS data.

Table 3: The latitude of location A and location B

	Latitude	Longitude
	Device	
Location A	6.05190	102.14640
Location B	1.86580	103.10060

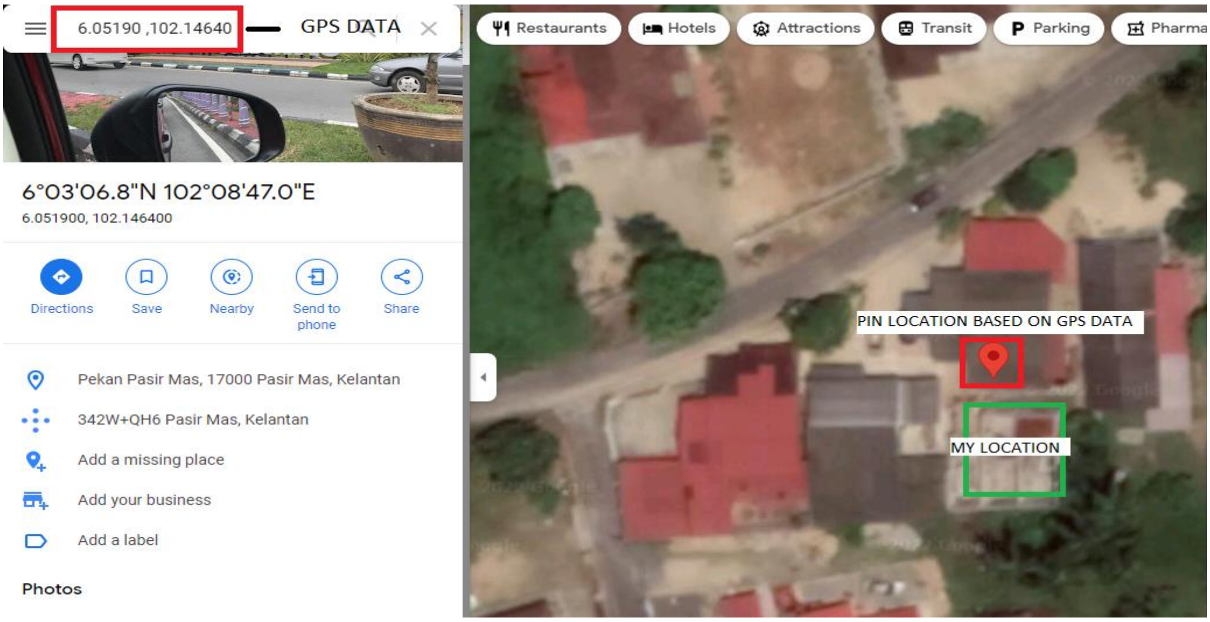


Figure 8: The GPS Location on Google Maps based on GPS data reading of Location A

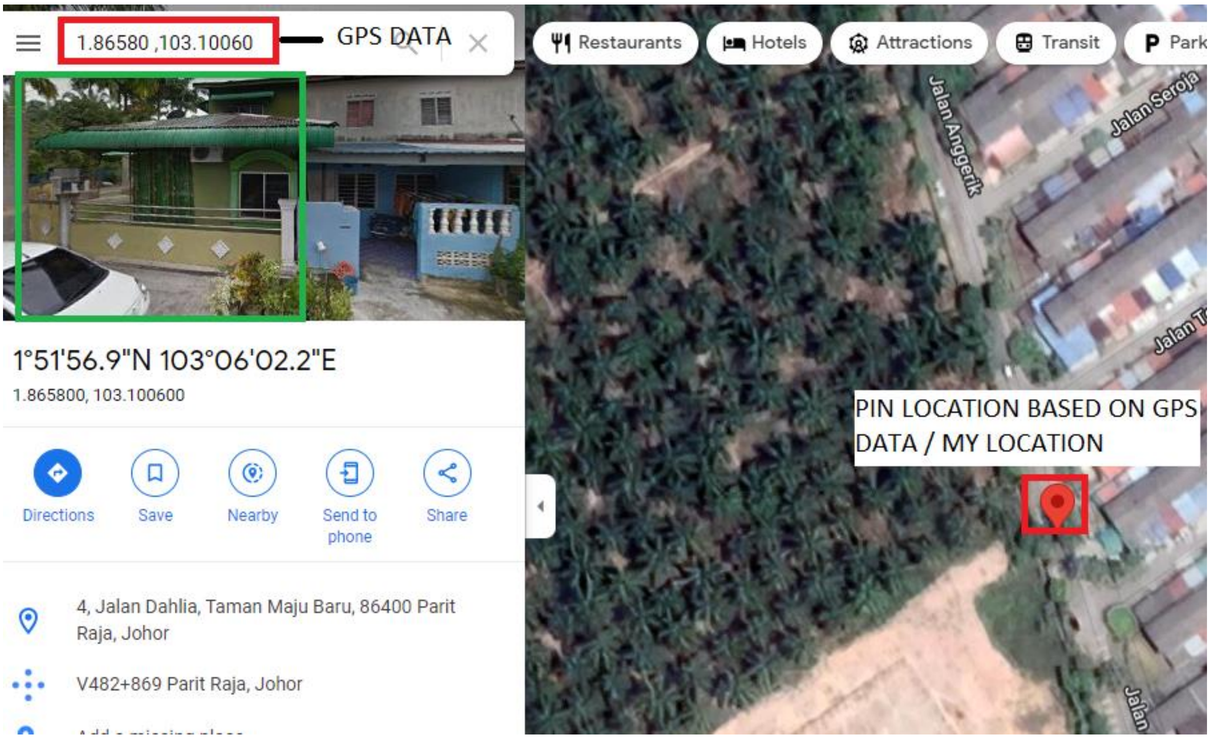
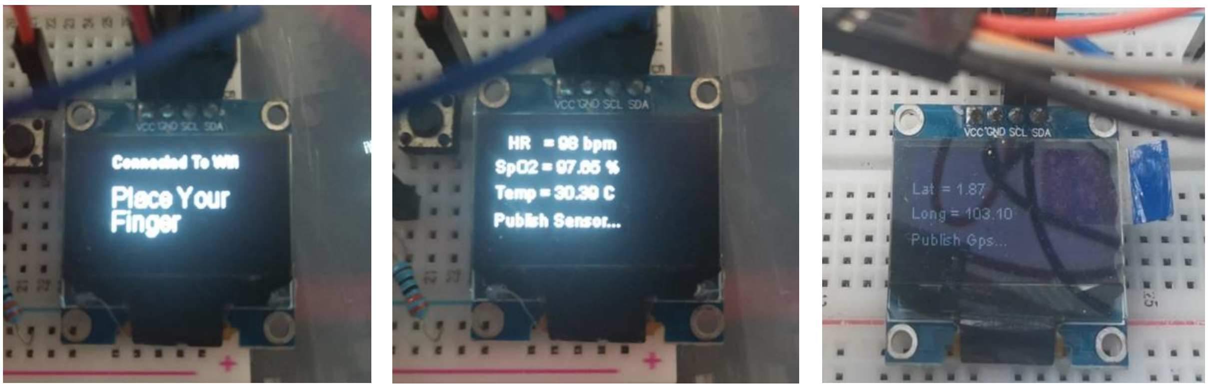


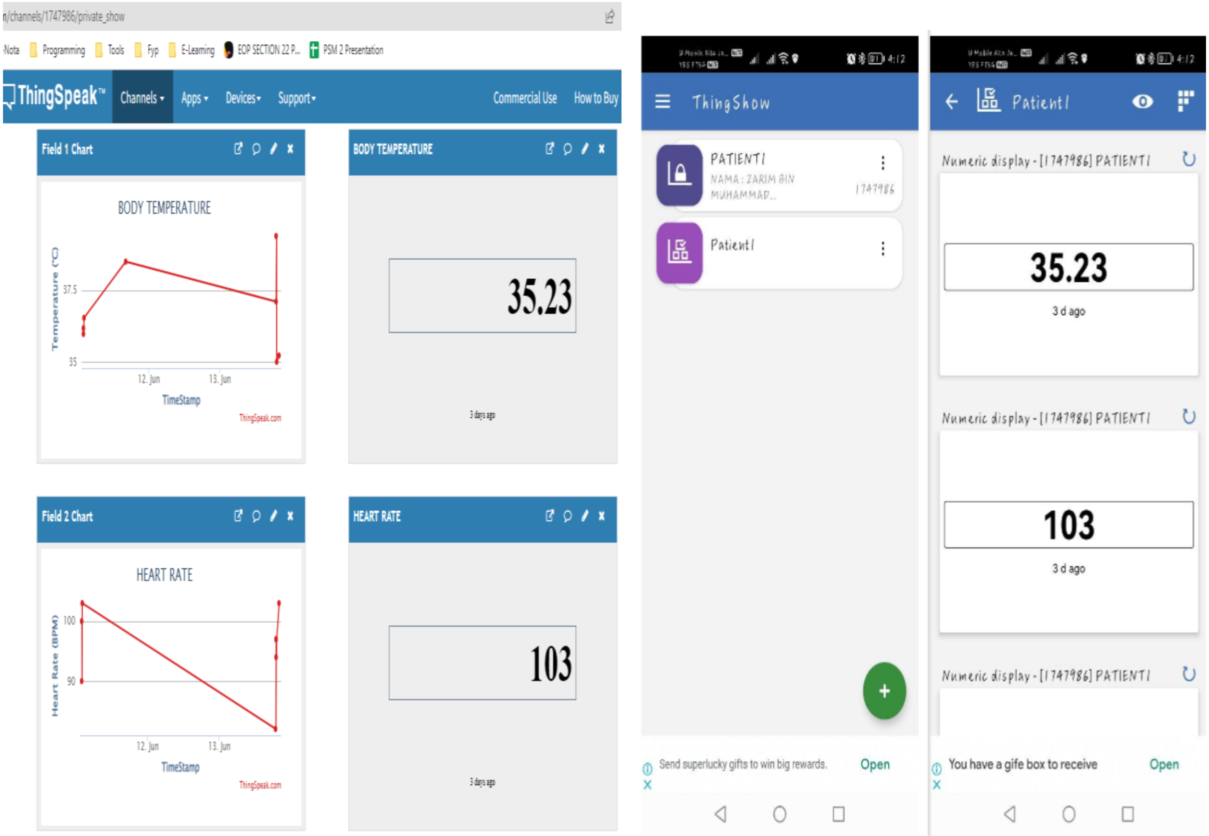
Figure 9: The GPS Location on Google Maps based on GPS data reading of Location B

Figure 8 demonstrates the output display of a health monitoring and tracking system device. Figure 8(a) depicts the device's initial display when turned on, Figure 8(b) depicts the output display of publishing basic health parameters to ThingSpeak, and Figure 8(c) depicts the output display of publishing GPS data location to ThingSpeak. Figure 9 shows the wireless monitoring system where the authorizer was able to monitor the real-time parameters from their web application or smartphone through the ThingSpeak platform. Figure 9 (a) shows the web interface for the ThingSpeak platform, while Figure 9 (b) shows the mobile application interface for the ThingSpeak platform. Figure 10 illustrates the notification received by the authorizer if the system detects any changes in the SpO2 and body temperature.



(a) (b) (c)

Figure 8: Health Monitoring and Tracking System Device (a) Initial display, (b) publishing basic health parameters to ThingSpeak, and (c) publishing GPS data location to ThingSpeak



. (a) (b)

Figure 9: The ThingSpeak platform (a) Web Apps version and (b) Mobile Apps version

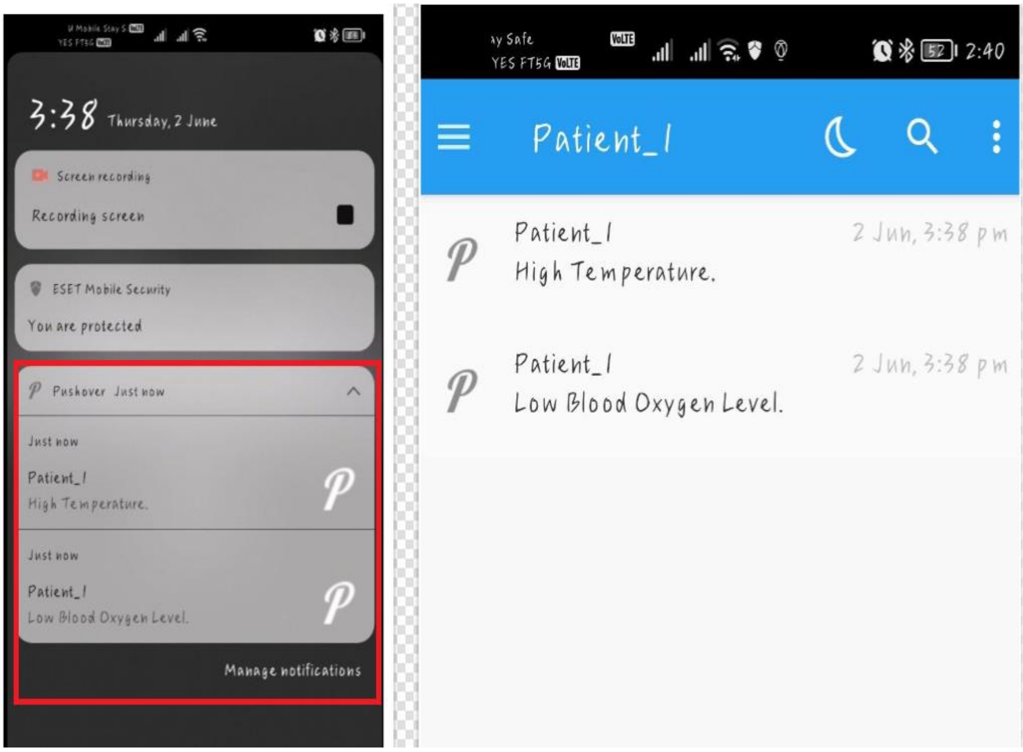


Figure 10: Notification System That Triggered by Pushover Notification Apps If High Temperature or Low SpO2

4. Conclusion

Overall, in this project, the IoT-based health monitoring and tracking system for self-quarantine of COVID-19 patients has been developed successfully as this system allows the authorised users, such as medical healthcare providers, to monitor the basic health parameters and the location of the patients wirelessly and without making regular contact. The medical healthcare providers are also able to receive notifications when the system detects any changes in the vital signs (i.e., SpO2 is less than 90% and the body temperature is greater than 37.5°C). Based on the results obtained, it shows a steady average of the heart rate per minute, the percentage of SpO2 and the body temperature also generated location by the GPS module are approximately close to each other if located using Google Maps. The results of basic health parameters are also accurate as they are similar to the devices that are on the market. However, there are a few limitations to this system, especially with the GPS module. Therefore, it would be better if there were a GPS module that could retrieve GPS data located inside the building (indoor). This system can also be improved by using another microcontroller that can cover a wider range of system design and materials.

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