Caring jacket: health monitoring jacket integrated with the internet of things for COVID-19 patients

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ABSTRACT

One of the policies that have been made by the World Health Organization (WHO) and the Indonesian government during this COVID-19 pandemic, is to use an oximeter for self-isolation patients. The oximeter is used to monitor the patient if happy hypoxia which is a silent killer, happens to the patient. To maintain body endurance, exercise is needed by COVID-19 patients, but doing too much exercise can also cause decreased immunity. That's why fatigue level and exercise intensity need to be monitored. When exercising, social distancing protocol should be also reminded because can lower COVID-19 spreading up to 13.6%. To solve this issue, the Caring Jacket is proposed which is a health monitoring jacket integrated with an IoT system. This jacket is equipped with some sensors and the global positioning system (GPS) for tracking. The data from the test showed the temperature reading accuracy is up to 99.38%, the oxygen rate up to 97.31%, the beats per minute (BPM) sensor up to 97.82%, and the precision of all sensors is 97.00% compared with a calibrated device.

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1. INTRODUCTION

The COVID-19 pandemic is happening everywhere including in Indonesia. This makes decreasing hospital capacity in many of Indonesia's cities such as Jakarta. At the beginning of the pandemic, Indonesia only had 1,910 ICUs with 7,094 critical care beds which means about 2.7 critical care beds per 100,000 population [1]. The availability of isolation beds which keeps decreasing is handled by directing some COVID-19 patients to do self-quarantine [2].

Self-quarantine with a period of 14 days is recommended to mitigate the additional spread of COVID-19 [3]. World Health Organization (WHO) issued a living guidance for COVID-19 self-quarantine patients who are not hospitalized to prepare pulse oximetry [4]. The purpose of using Pulse Oximetry is to routinely check the patient's oxygen rate and to prevent the situation when the oxygen rate is suddenly lowered without any symptoms or usually called happy hypoxia [5]. According to [6], lots of people die due to improper information about health. In a cohort study on COVID-19 patients in Wuhan with severe symptoms, 19% of them experienced out of breath. Of 62% of patients with severe symptoms, 46% of them had to do incubation, mechanical ventilation, or even death [7]. In some cases that culminate in ventilation and even death, then a change in strategy for handling patients needs to be done, and it could be done by using a pulse oximeter.

One way to help the self-quarantine patient to keep their immune system is by exercising. However, exercising too much can also decrease body immunity because of the effect of depressants on the body [8]. Therefore, it is necessary to monitor the level of fatigue and control the intensity of exercise. When exercising, especially when doing self-quarantine, it is important to keep a distance (1 meter) from others [3]. The percentage risk of spreading the COVID-19 virus shows a value of around 2.6% between individuals with a physical distancing of at least 1 meter, while at less than 1 meter the risk reaches 13.6% [9].

The internet of things (IoT) is a technology that can connect physical objects to the Internet. Its application is broad including cities, homes, industries, agriculture, hospitals, and health [10]–[12]. IoT has an important role in better care of the patient during COVID-19, real-time monitoring of patient conditions helped to save lives [13]. Some applications of IoT during a COVID-19 pandemic are the treatment of COVID-19 patients [14]–[16], smart hospitals [17]–[20], accurate decision-making [21]–[23], monitoring the status of the patients [24]–[26], and emergency case [27], [28].

Some research with the purpose to create pulse oximetry, detecting fatigue levels, and developing the application system of physical distancing has been done. Iswanto and Megantoro [29] created a device to detect hypoxia early symptoms using the non-invasive method with MAX30100, while Ace *et al.* [30] use piezoelectric and a passive infrared sensor (PIR) sensors to detect pneumonia through sleep disturbance. Patel *et al.* [31] create heart rate monitoring based on IoT to detect a heart attack. But there aren't any devices that have three of those functions.

The purpose of this research is to develop an innovation in the form of a jacket where the data related to oxygen levels and fatigue levels are stored in the patient medical records connected to smartphones via IoT so that the result can also be viewed by family members or doctors. In addition, a GPS feature allows searching the user's location if the user's medical record shows poor results or when the user cannot be contacted. Also, a buzzer as a reminder of physical distancing. This research was conducted with the aim of optimizing the components used in the integrated IoT system implemented in a jacket as a multifunctional tool for COVID-19 patients.

The rest of the paper will be organized. Section 2 will provide a review of the material and method used in this research, system design, and flow algorithm. Then, the hardware implementation results will be discussed in section 3. The last section is the conclusion.

2. MATERIAL AND METHOD

2.1. Material

The schematic diagram of the proposed system is shown in Figure 1. It consists of ESP8266 as a processor, two sensors which are MAX30102 and PIR sensor, a GPS module, and a buzzer. The MAX30102 sensor is used to detect heart rate, oxygen levels, and body temperature placed on the wrist of the jacket. The body temperature was measured using an on-chip temperature sensor of MAX30102. Although it is not as well as a stand-alone temperature sensor, it can reduce the cost and the complexity. The GPS is used to detect the location where the user is located, placed on the back of the jacket. The PIR sensor is used as a distance sensor in the implementation of physical distancing, placed on the back of the jacket. As the controller for caring jacket, ESP8266 microcontroller unit (MCU) node is the main controller and IoT media. The controller is placed on the inside of the jacket. In addition, caring jacket is also equipped with a slot to place a power bank as a source of electrical energy for the system. The caring jacket design is shown in Figure 2. The caring jacket system has been equipped with IoT technology using the Blynk application with a display as shown in Figure 3.

From the Blynk application, it is possible to monitor the user's health condition in real-time using an Android smartphone. To start the app, the user must log in to his/her registered account. After that, the connection to the jacket will automatically run when the sensor system in caring jacket is turned on. One account can be used on more than one device; therefore, the user family can monitor the user's health too. This app will work if there are indications of health problems by caring jacket users. When the system read a health problem, the system will send a notification via the app. In addition, it is also equipped with a feature connected to Google Maps, so that when there is an indication of health problems from the user, the user's family or closest person can immediately go to the user's location.

2.2. Method

The implementation stages of this research consist of several stages. Starting with the study of literature by searching for reference sources in journals, papers, articles, and other sources with related information. After that, designing the device to solve`` the problem. Controller system assembly is done by assembling MAX30102, GPS, PIR sensor, and Buzzer in parallel with app design. Then test both hardware and software and evaluate for some mistakes found. After the system can run on the app finely, make packaging and combine the system into a jacket. After all controller and IoT systems are combined with the jacket, then testing the system, collecting data, and analyzing the performance of the device.

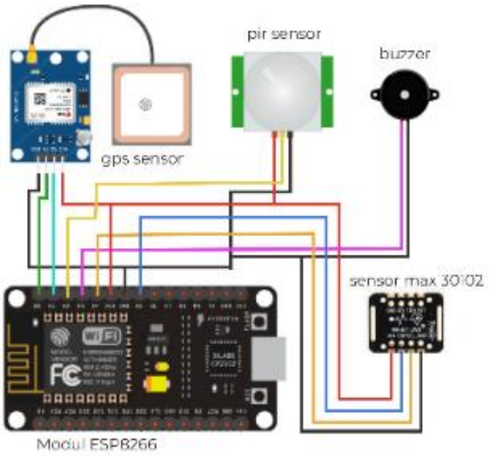

Figure 1. Schematic diagram of the proposed system

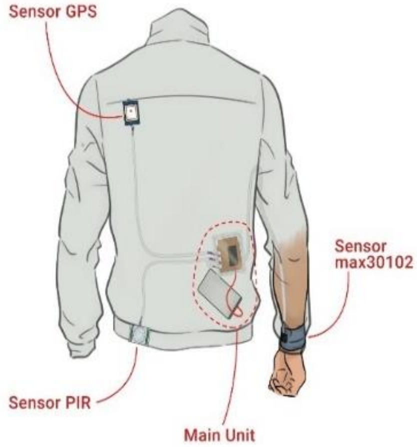

Figure 2. Caring jacket and the component placement design

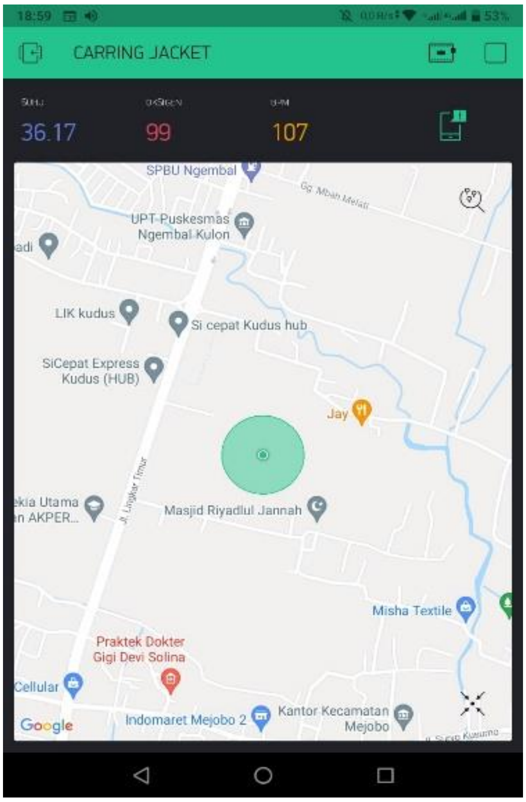

Figure 3. Application graphical user interface (GUI) design

Figure 4 shows the working process of the proposed system. All the sensors work in parallel. GPS detects the device's location and compares it with the smartphone's location. If it matches, then stored in the developed application. MAX30102 sensor reads body temperature, oxygen saturation, and heart rate. Then compare the reading result with the health standard, if it is in the standard range determined as good health and vice versa. The last, the PIR sensor detects if there is anyone with a distance below 1m and activates the buzzer as a notification. The information from GPS and MAX30102 is stored in the cloud and displayed in the developed application.

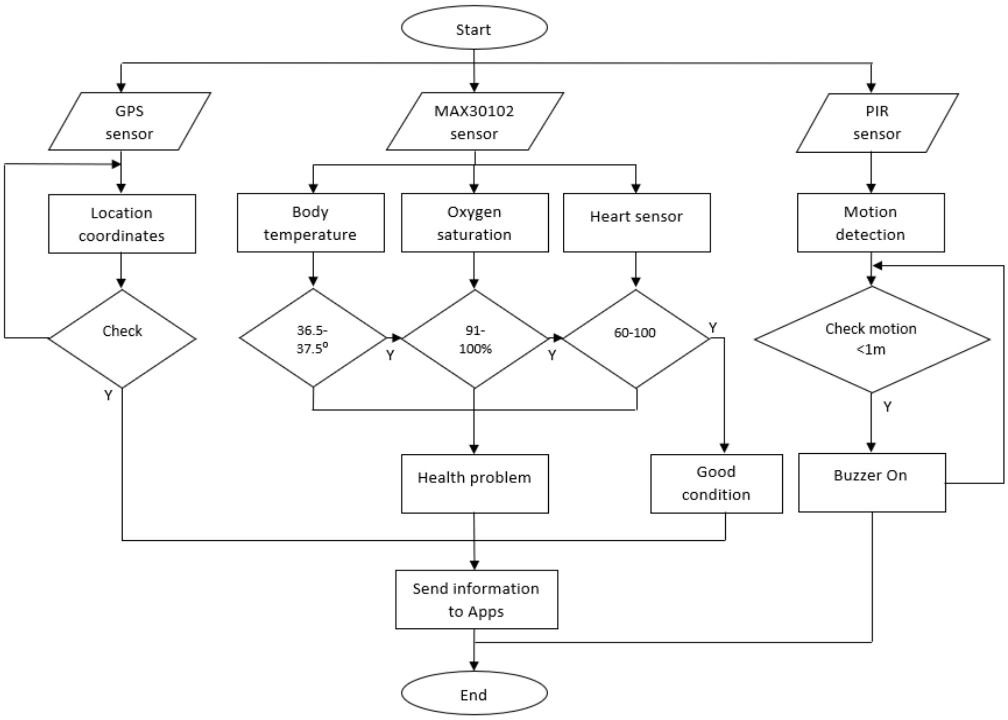

Figure 4. Working process of the proposed system

3. RESULTS AND DISCUSSION

After the system including both hardware and software works well, then it is packed in a jacket and tested. Figure 5 shows when the jacket is used by a man. The caring jacket is a jacket that has been equipped with several sensors such as MAX30102, PIR, and GPS sensor. In this test, the accuracy of the sensors is tested. Table 1 shows the temperature sensor's accuracy by comparing the measurement result of the MAX30102 sensor on the Caring Jacket with a thermometer. It is seen that the accuracy of the temperature sensor is high which is 99.38%. Testing results of the level of O_2 accuracy are shown in Table 2 and the pulse rate is in Table 3, by comparing the results of the MAX30102 on the Caring Jacket with pulse oximetry. The accuracy of O_2 and BPM sensors is 97.31% and 97.82%, respectively.

Table 1. Temperature sensor accuracy

Test Object	*Caring Jacket* (ºC)	Thermometer (ºC)	Error (%)
Person 1	36.0	35.9	0.28
Person 2	35.6	36.2	1.66
Person 3	36.1	35.8	0.84
Person 4	36.4	36.4	0.00
Person 5	35.9	36.0	0.28
Error average			0.62
Device accuracy			99.38

Table 2. O_2 sensor accuracy

Test Object	*Caring Jacket* (%SpO_2)	*Oximeter* (%SpO_2)	*Error* (%)
Person 1	95	96	1.04
Person 2	92	97	5.15
Person 3	98	99	1.01
Person 4	99	96	3.12
Person 5	98	95	3.15
Error average			2.69
Device accuracy			97.31

Table 3. Oximeter sensor accuracy

Test Object	*Caring Jacket* (BPM)	*Oximeter* (BPM)	*Error* (%)
Person 1	80	78	2.56
Person 2	108	107	0.93
Person 3	96	101	4.95
Person 4	88	89	1.12
Person 5	76	75	1.33
	Error average		2.18
	Device accuracy		97.82

Testing the GPS accuracy by comparing the measurement results of the GPS sensor on the Caring Jacket with Google Maps on the smartphone is shown in Table 4. It informs that the distance average error is 34.84m. Table 5 shows the level of precision of the MAX30102 on the caring jacket by recording changes in sensor reading data. The temperature, O_2, and BPM precision are over 97%. The last, the precision level of the GPS sensor is shown in Table 6. It is recorded that, from ten measurements, all give the same result, meaning the precision is 100%. Figure 6 shows the example monitoring system in the developed Application. The data monitoring system can monitor the oxygen levels and the BPM rate. The reference data for a person's health based on the parameters of body temperature, heart rate, and oxygen level used are shown in Table 7.

Table 4. GPS sensor accuracy

Test Object	*Caring Jacket* (Coordinate)	*Google Maps* (Coordinate)	Difference (m)
Place 1	-7.564, 110.857601	-7.564200, 110.85750	12.2
Place 2	-6.827893, 110.88360	-6.827355, 110.88335	50.0
Place 3	-7.561359, 110.85409	-7.561651, 110.85428	40.0
Place 4	-7.562152, 110.85703	-7.562425, 110.85687	35.0
Place 5	-7.561812, 110.85381	-7.562105, 110.85367	37.0
	Distance Average Error		34.84

Table 5. MAX30102 sensor precision

Time (s)	Temperature (ºC)	O_2 (%SpO_2)	BPM
1	36.38	91.02	96.64
2	36.35	95.13	98.34
3	36.36	96.06	95.77
4	36.39	96.12	96.23
5	36.39	96.34	99.18
6	36.35	97.67	100.31
7	36.39	97.72	103.26
8	36.36	97.46	97.46
9	36.39	96.45	96.45
10	36.39	97.82	97.82
SD	0.045	2.02	2.32
Precision	99.96 %	97.98 %	97.68 %

Table 6. GPS sensor precision

Second(s)	Coordinate
1	-6.827893, 110.883607
2	-6.827893, 110.883608
3	-6.827893, 110.883609
4	-6.827893, 110.883610
5	-6.827893, 110.883611
6	-6.827893, 110.883612
7	-6.827893, 110.883613
8	-6.827893, 110.883614
9	-6.827893, 110.883615
10	-6.827893, 110.883616
Precision	100%

Table 7. Classification of body fatigue [9]

Body Temperature	Pulse (BPM)	Oxygen Level	Classification
36.5-37.5°C	60-100	91-100%	Normal
>37.5-38°C	101-110	80-90%	Tired
>38°C	>110 or <60	<80%	Drop (Very Tired)

Figure 5. Caring jacket used by a man

Figure 6. Caring jacket app monitoring: BPM data

4. CONCLUSION

Exercise is needed by COVID-19 patients, but doing too much exercise can also cause decreased immunity. That's why fatigue level and exercise intensity need to be monitored. When exercising, social distancing protocol should be also reminded. To solve this issue, the Caring Jacket is proposed which is a health monitoring jacket integrated with an IoT system. Caring Jacket can store data related to the user's oxygen rate and fatigue level on a medical record that can be accessed by the user via smartphone and can also receive by a family member or doctors in real time. A GPS feature can also be used for sharing the user's location when the medical record shows a bad result, and the user cannot be reached. The buzzer at the backside of the jacket is used for physical distancing reminders. From the testing that has been done, Caring Jacket has a level of accuracy and precision of more than 97%. Besides that, the proposed system also has some limitation such as the power supply which still use a power bank making it not flexible. The device must be taken off before the jacket is washed; therefore, in the future, better packaging which makes it easy to take care of must be considered.

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