IoT Based Cytokine Storm Symptoms Early Warning System for Covid-19 Self-Isolating Patient

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***Abstract*—Covid-19, which has spread throughout the world, has reportedly caused millions of deaths. Among the causes of the patient's death is the phase after the patient is declared negative for COVID, but there is a cytokine storm. In this study, an IoT-based technology was proposed to be able to detect abnormalities in COVID-19 patients, even though they already had a negative Covid status based on the PCR test. The implementation of this technology allows former Covid patients to be monitored from anywhere as long as they are connected to the internet, using designed wearable devices and dedicated mobile apps for them. Based on experiment result, all the sensors have the ability to work and sense patient body indicators with error below 5%. This study demonstrated the flawless use of a mobile app dedicated to monitor patients' health during the pandemic. When patient health condition indicating exposed to cytokine storm, a warning notification is appear at the mobile app.**

Keywords—Covid-19, IoT Telemedicine, microcontroller

I. Introduction

According to data released by Indonesian Ministry of Health, the number of confirmed positive cases as of November 4, 2021 is 4,246,802 people with a death toll of 143,500. From this situation, it is known that the case fatality rate due to COVID-19 is around 3.4%. When classified by age, the age group >60 years has a higher percentage of mortality rates than other age groups. Meanwhile, when classified from gender, 52.3% of patients who died from COVID-19 were male and the remaining 47.7% were female. Although the number of deaths from COVID-19 is relatively high, the recovery rate from COVID-19 is also increasing. The latest data states, the number of survivors or people who have been infected with the Corona virus and then recovered is 6,301,694 people [1].

Internet of Things (IoT) as a technology that can connect objects with one another as long as they are connected to the internet has become a technology trend in the last 10 years. IoT can be used to solve problems in various fields including energy management [2], control of electronic devices by voice [3], agriculture [4], energy monitoring [5], remote device control [6], including the health sector [7]. Research on medical electronics shows that body health parameters can be observed and analyzed [8]-[12]. By utilizing IoT technology and medical electronics, a system that can be intelligently and remotely controlled can be built to solve the problem of the COVID-19 pandemic.

II. Method

Early symptoms of Corona virus infection or COVID-19 can resemble flu symptoms, such as fever, runny nose, dry cough, sore throat, and headache. After that, the symptoms may disappear and heal or even worsen. Patients with COVID-19 with severe symptoms may experience high fever, cough with phlegm and even blood, shortness of breath, or chest pain. These complaints arise when the body reacts to the Corona virus.

Cytokine storm is one of the possible complications in COVID-19 patients. This condition should be monitored and treated intensively. Cytokine storms can lead to organ failure and even death if left untreated. Cytokines are proteins that play a role in the immune system. Under normal conditions, cytokines help the immune system adjust properly against infection-causing bacteria and viruses. However, when overproduced, cytokines can actually damage the body—this is known as a cytokine storm [13].

A. Cause of Cytokine Storm

A cytokine storm occurs when the body releases too many cytokines into the blood too quickly. This condition causes immune cells to attack healthy body tissues and cells, causing inflammation. This condition is known from her D-dimer and CRP studies in COVID-19 patients.

Inflammation often leads to damage and loss of function of the body's organs. For this reason, cytokine storms can be lethal and should be taken with caution. In patients with COVID-19, a cytokine storm attacks lung tissue and blood vessels. The alveoli, or small air sacs in the lungs, fill with fluid and are unable to exchange oxygen. As such, patients with COVID-19 often suffer from shortness of breath [13].

B. Symptoms of a Cytokine Storm

Most people with COVID-19 who experience a cytokine storm have fever, shortness of breath, and require a breath stone or ventilator. This condition usually occurs about 6-7 days after symptoms of COVID-19 appear.

In addition to fever and shortness of breath, cytokine storm also causes a variety of symptoms such as seizures, uncontrolled movements, confusion and hallucinations, extreme hypotension, and blood clotting [13].

C. The Telediagnosis System Design

To perform telediagnosis, the patient must wear a smart bracelet with sensors for performing remote diagnosis, as shown in Figure 1. A Max 30102 sensor was used to record oxygen saturation and heart rate. A push button was used to operate the smart bracelet device and a temperature sensor LM35DM was used to detect the patient's body temperature. In addition, the WEMOS D1, which is small and equipped with a WiFi connection function, is used for the processor. The data was immediately displayed on the OLED and sent to Google Firebase used as the cloud. Patient data on Google Firebase can be monitored by medical staff using smartphones. A block diagram of the remote diagnostic system is shown in Figure 2.

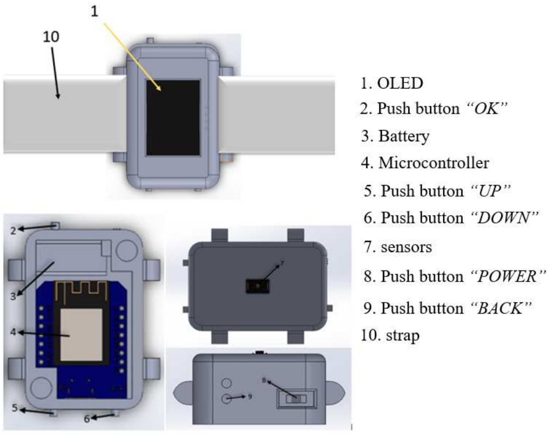

Fig. 1. Smart wristband for telediagnosis system

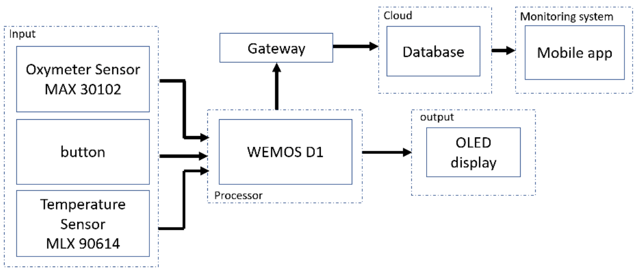

Fig. 2. The telediagnosis system diagram block

III. RESULTS

A. The Patient Body Temperature Measurement Test

This test was performed to calibrate the LM35DM sensor on the console using a digital thermometer. First, we used the LM35DM sensor with an esp32 microcontroller to calibrate the body temperature. The Arduino Nano's ADC and esp32 have the following differences: B. Unstable noise. So that led me to use LPF (Low Pass Filter) to get the sensor data and remove the high frequency noise.

A calibration was performed to check the body temperature and compare the results with mi digital thermometer. ADC sampling ran for 1 minute and after some observations determined the x value as follows:

$$x = \frac{201.79}{30.3} \quad (1)$$

where 201.7 and 30.3 °C are the 1 minute average ADC and temperature. So using this formula, x equals 6.7639344262 and the Temp value is determined as follows:

$$TEMP = \frac{ADC}{6.7639344262} \quad (2)$$

To accurately measure body temperature, the LM35DM is usually worn under the arm. In this study, this sensor will be worn on the wrist as part of his smart bracelet. Based on initial test results, wrist and armpit measurements differ by 2°C. Therefore, in addition to linear regression, data normalization is also performed for the calibration process, as shown in Table 1.

TABLE I. PATIENT BODY TEMPERATURE MEASUREMENT RESULT

NO	LM35DM located at wrist (°C)	Data normalization	Data after Filtering	mi medical Thermo-meter	deviation
1	34.01	36.01 °C	35.97 °C	35.8 °C	0.17 °C
2	34.46 °C	36.46°C	35.92°C	35.8 °C	0.12 °C
3	32.95 °C	34.95 °C	35.27 °C	35.3 °C	0.03 °C
4	33.40 °C	35.40 °C	35.94 °C	35.4 °C	0.54 °C
5	31.89 °C	33.89 °C	34.58 °C	34.8 °C	0.38 °C
6	31.89 °C	33.89 °C	33.79 °C	33.7 °C	0.09 °C
7	32.95 °C	34.95 °C	34.84 °C	34.5 °C	0.34 °C
8	31.44 °C	33.44 °C	33.58 °C	33.8 °C	0.22 °C
9	31.29 °C	33.29 °C	34.12 °C	34.3 °C	0.18 °C
10	31.13 °C	33.13 °C	34.40 °C	34.3 °C	0.10 °C

ESP32 was used to obtain the room temperature formula on the LM35DM sensor.

$$\text{Average error value} = \sum\text{deviation}/\sum\text{samples} = 2.17/10 = 0.217\ \% \quad (3)$$

In the table, the measurement data was obtained by taking 10 samples. The data was obtained by putting the LM35DM sensor on the patient's wrist for 15 seconds, while simultaneously taking data on a mi medical thermometer. A comparison graph of the sensor with mi medical thermometer of body temperature is shown in Fig. 3.

B. The Patient Oxygen Saturation Levels Measurement Test

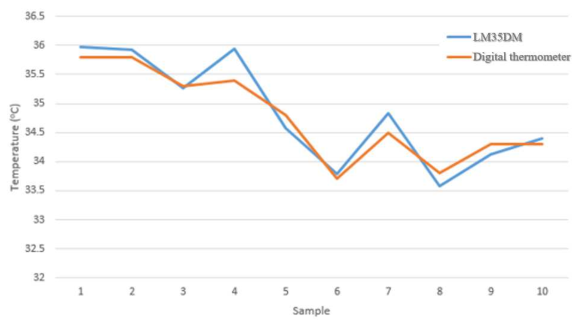

Fig. 3. The comparison graph of LM35DM sensor with mi digital thermometer

Sensor testing is conducted by measuring patient oxygen saturation level. This process is carried out by first applying the code in the WEMOS D1 microcontroller, as follows:

```
int sampleRate - 1000: //Options: S0, 100, 200, 400, 800, 1000, 1600, 3200
int pulsemidch – 411; //Options: 69, 118, 215, 411
int adcRange – 16384; //Options: 2048, 4096, 8152, 16384
```

In the calibration process, the oxygen saturation levels measured from the max30102 sensor is compared with a digital Oximeter model P-01 measuring instrument. Each sample with total measurement of 10 seconds is compared with the average for every 1 second. The comparison result is shown in Table 2.

TABLE II. PATIENT OXYGEN LEVELS MEASUREMENT RESULT

NO	Sensor Max 30102	digital Oximeter Model : P-01	deviation
1	96.3	96	0.3
2	98	97	1
3	97.9	97	0.9
4	98.3	98	0.3
5	98.4	98	0.4
6	98.9	98	0.9
7	99	99	0
8	99	99	0
9	97.4	97	0.4
10	98.5	98	0.5

Table 2 showed that data deviated from these measurements, therefore the average error is calculated as follows:

Average error value = ∑deviation/∑samples (4)
= 4.7/10
= 0.47%

The comparison results can be illustrated with a graph as shown in Fig. 4.

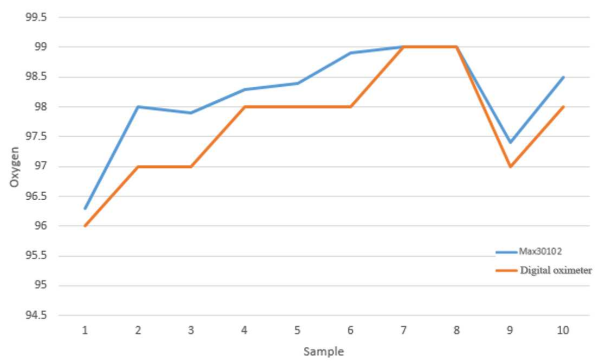

Fig. 4. The oxygen saturation levels measurement result from max30201 sensor vs digital oximeter model P-01

C. The Patient Heart Rate Measurement Test

The sensor test is performed by comparing the readings from the Max 30102 sensor to those of a calibrated heart rate monitor model: P-01. It is important to set the code on the WEMOS D1 microcontroller as follows:

```
int sampleRate - 1000: //Options: S0, 100, 200, 400, 800, 1000, 1600, 3200
int pulsemidch – 411; //Options: 69, 118, 215, 411
int adcRange – 16384; //Options: 2048, 4096, 8152, 16384
```

In this calibration process, the heartbeat rate measurement results are compared with the MAX30102 sensor from the digital Oximeter measuring instrument. The comparison results are shown in Table 3.

TABLE III. PATIENT HEART RATE MEASUREMENT RESULT

NO	max30102 Sensor	digital Oximeter Model : P-01	deviation
1	65	69	4
2	67	68	1
3	69	75	6
4	74	79	5
5	78	81	3
6	82	87	5
7	84	89	5
8	87	90	3
9	101	105	3
10	102	106	3

Table 3 shows that there is data deviation from the results of the comparison of the max30102 sensor with a digital oximeter. Therefore, it can be concluded that the average error in the comparison is as follows:

Average error value = ∑deviation/∑samples (5)
= 38/10
= 3.8%

The comparison results are illustrated with a graph, as shown in Fig. 5.

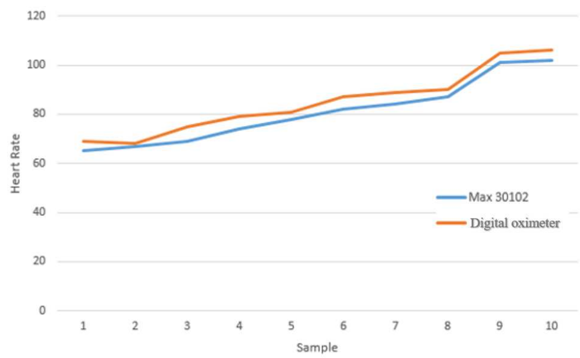

Fig. 5. The comparison graph of max30201 heart rate sensor with digital oximeter model P-01

D. Mobile App For Cytocine Early Detection

The Cytokine Storm App is a smartphone application for early detection of the likelihood that patients who have recovered from COVID-19 will experience a cytokine storm. This cytokine storm usually occurs in a Covid-19 patient's second week of first symptoms. Initially healthy patients suddenly experience a dramatic deterioration in their condition as the body's antibody system reacts negatively and attacks healthy body cells, leading to death from organ failure. Parameters measured were heart rate per minute, body temperature and oxygen saturation level using dummy data based on the real possible parameter range of cytokine storm, laboratory only. measurement test.

The first display in the application is the patient profile, followed by real-time measurements of the patient's heart rate data, oxygen saturation value, and body temperature. On the same page is a calendar with information about appointments for patients with early symptoms of COVID-19. In the calendar, the user can check the patient's status to indicate if this patient is in normal condition or in cytokine her storm. The Google Cloud Firebase corresponding to each sensor is shown in Figure 6.

Mobile app interface as shown in Fig. 7 indicating the patient condition is normal because of oxygen >92% and body temperature <38 celcius. While Fig. 8 indicates that the patient is experiencing a cytokine storm status due to body temperature is 38^0C while the oxygen saturation level is 90%. In the mobile app, there is a notification to indicate the patient is experiencing a cytokine storm, so that medical staff could understand the patient situation immediately.

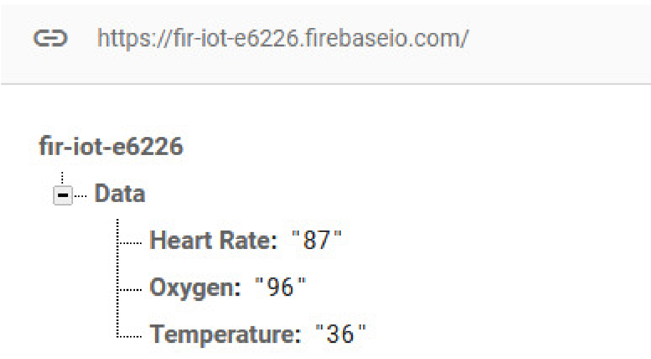

Fig. 6. Google cloud database

Fig. 7. Possible mobile app status when patient in normal condition

Fig. 8. Possible mobile app status when patient in cytokine storm condition

IV. CONCLUSION

In conclusion, this study successfully demonstrated a new approach for covid-19 telediagnosis system using IoT technology. Sensors in the smart wristband were designed to check the body health parameter for covid-19 patient such as body temperature, oxygen saturation level and heartbeat. The use of these parameters makes it easier for doctors to monitor covid-19 patients remotely.

Based on experiment result, all the sensors have the ability to work and sense patient body indicators at an average acceptable error rate of 0.217 % for the patient body temperature error rate., 0.47% for the patient oxygen saturation level error rate, while 3.8 % for the patient heartbeat error rate. This study also demonstrated the flawless use of a mobile app dedicated to monitor patients' health during the pandemic. When patient in wrong condition, the system will notify medical staff to immediately take care the patient, to lessen the effect of cytokine storm.

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REFERENCES

[1] https://covid19.kemkes.go.id/ [accessed at October 2022]

[2] M. S. Hadi, M. R. Maulana, M. A. Mizar, I. A. E. Zaeni, A. N. Afandi and M. Irvan, "Self Energy Management System for Battery Operated Data Logger Device Based on IoT," 2019 International Conference on Electrical, Electronics and Information Engineering (ICEEIE), Denpasar, Bali, Indonesia, 2019, pp. 133-138, doi: 10.1109/ICEEIE47180.2019.8981406.

[3] M. S. Hadi, M. A. A. Shidiqi, I. A. E. Zaeni, M. A. Mizar and M. Irvan, "Voice-Based Monitoring and Control System of Electronic Appliance Using Dialog Flow API Via Google Assistant," 2019 International Conference on Electrical, Electronics and Information Engineering (ICEEIE), Denpasar, Bali, Indonesia, 2019, pp. 106-110, doi: 10.1109/ICEEIE47180.2019.8981415.

[4] M. S. Hadi, P. Adi Nugraha, I. M. Wirawan, I. Ari Elbaith Zaeni, M. A. Mizar and M. Irvan, "IoT Based Smart Garden Irrigation System," 2020 4th International Conference on Vocational Education and Training (ICOVET), Malang, Indonesia, 2020, pp. 361-365, doi: 10.1109/ICOVET50258.2020.9230197.

[5] M. S. Hadi, T. S. Wisanggeni, D. Lestari, A. N. Afandi, A. P. Wibawa and M. Irvan, "Realtime Potential Energy Monitoring and Data Logging Systems on the River Flow for Micro Hydro Power Plants," 2020 4th International Conference on Vocational Education and Training (ICOVET), Malang, Indonesia, 2020, pp. 1-6, doi: 10.1109/ICOVET50258.2020.9230109.

[6] M. Sholihul Hadi, M. Samsul Huda, I. Ari Elbaith Zaeni, M. Alfian Mizar and M. Irvan, "IoT Embedded System for Automatic Tissue Processor Machine," 2020 4th International Conference on Vocational Education and Training (ICOVET), Malang, Indonesia, 2020, pp. 1-6, doi: 10.1109/ICOVET50258.2020.9230048.

[7] Mokh Sholihul Hadi, Ilham Ari Elbaith Zaeni, Mohamad Dana Maulana, Aji Prasetya Wibawa, Arif Nur Afandi. IOT Cloud data logger for Heart Rate Monitoring Device. 2nd International Conference on Vocational Education and Training (ICOVET 2018). Atlantis Pers.

[8] Chen, Yeou-Jiunn; Chen, Shih-Chung; Zaeni, Ilham AE; Wu, Chung-Min; ,Fuzzy tracking and control algorithm for an SSVEP-based BCI system,Applied Sciences,6,10,270,2016,Multidisciplinary Digital Publishing Institute

[9] Chen, Shih-Chung; Wu, Chung-Min; Zaeni, Ilham AE; Chen, Yeou-Jiunn; ,Applying fuzzy decision for a single channel SSVEP-based BCI on automatic feeding robot,Microsystem Technologies,24,1,199-207,2018,Springer Berlin Heidelberg

[10] Zaeni, Ilham AE; Pujianto, Utomo; Taufani, Agusta R; Jiono, Mahfud; Muhammad, Pradareza ST; ,Concentration Level Detection Using EEG Signal on Reading Practice Application,"2019 International Conference on Electrical, Electronics and Information Engineering (ICEEIE)",6,,354-357,2019,IEEE

[11] Zaeni, Ilham AE; Jiono, Mahfud; ,Detection of Fear of Falls using PPG with Video Stimulation of the Fall Condition,2019 International Biomedical Instrumentation and Technology Conference (IBITeC),1,,93-97,2019,IEEE

[12] Rochmah, Afiatur; Sendari, Siti; Zaeni, Ilham AE; ,Sleepiness Detection For The Driver Using Single Channel EEG With Artificial Neural Network,"2019 International Conference on Advanced Mechatronics, Intelligent Manufacture and Industrial Automation (ICAMIMIA)",,,80-85,2019,IEEE.

[13] https://www.alodokter.com/virus-corona [accessed at November 2021]