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Smartband for Heartbeat and Oxygen Saturation Monitoring with Critical Warning to Paramedic via IoT

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ABSTRACT There are vital signs in the human body that indicate important physiological values for the body. In the COVID-19 pandemic, some of the important vital signs that must be monitored are BPM (Beats Per Minute) and SpO2 (oxygen saturation) as indicators of whether a person is in good health or lacks oxygen to predict the early symptoms of COVID-19. The purpose of this study is to create a device on the patient's wrist that can monitor BPM and SpO2 in real-time, as well as provide notifications on smartphones and emails when the patient's condition is abnormal. The contribution of this study is to implement an IoT (Internet of Things) system using a Wi-Fi connection so that monitoring activities are not separated by distance and time. The MAX86141 sensor is used in the design of this tool to detect the BPM and SpO2 values, after which the data is processed and displayed on the ESP32 TTGO T-Display. Monitoring results are also sent to the Blynk, and if the patient's condition is abnormal, an email notification is sent. According to the tool testing results, BPM has the smallest error of 0.94 percent and the largest error of 6.48 percent, whereas SpO2 has the smallest error of 0.20 percent and the largest error of 3.23 percent. The findings of this study can be used to improve the ease and efficiency of body health monitoring activities. This has the potential to significantly improve public health service quality, particularly during the COVID-19 pandemic.

INDEX TERMS Blynk, BPM, ESP32 TTGO T-Display, MAX86141, SpO2

I. INTRODUCTION

One of the most important factors that can improve community life is health. Health equipment is one of the supports for the advancement of community health services. With the advancement of technology, many sophisticated medical devices have been created to diagnose disease, treat disease, cure disease, and support and maintain the life of patients [1]. Several vital signs in the human body indicate a critical function for the human body. These vital signs represent the significance of human physiological functions such as blood pressure, body temperature, oxygen saturation, pulse rate, and respiratory rate [2]. These vital signs can indicate whether or not a person is healthy [3]. Some of the vital signs that must be monitored during the COVID-19 pandemic are BPM (Beat Per Minute), which is the number of heartbeats per unit time expressed per minute or Beat Per Minute (BPM), and oxygen saturation or SpO2, which is a health benchmark for measuring the amount of oxygen in the bloodstream. BPM (Beats Per Minute) and SpO2 (oxygen saturation) to determine if a person is in good health or lacks oxygen to predict early COVID-19 symptoms [4]. The World Heart Federation reports that heart disease is the cause of death for more than 17 million people every year. Normal heart rate ranges from 60-100 BPM. There are several abnormal conditions in the heart rate due to a wrong lifestyle such as a heartbeat that is too fast (tachycardia), too slow (bradycardia), or irregular (arrhythmia) even when you are not active. Abnormalities of increased heart rate are associated with cardiovascular mortality in the general population and patients with ischemic heart disease. Atrial fibrillation with persistent rapid ventricular rates is the most common cause. The first reported case of death was from the study of Framingham, Levy et al. that transient tachycardia alone or associated with transient hypertension is a prognostic risk factor in the general population. The mortality rate in patients with a heart rate above 100 BPM is more than two times greater than in patients with a heart rate less than 100 BPM. Death due to abnormal heart rate conditions can be prevented if first aid is given when an abnormal heart rate condition is detected. The SARS-CoV-2 virus, which causes Coronavirus Disease 2019 (COVID-19), has been declared a pandemic by the World Health Organization (WHO) since March 11, 2020, and has infected more than 54 million people and killed more than 1.3 million people as of November 14, 2020. Infection with SARS-CoV-2 causes pneumonia with respiratory failure, which is similar to Acute Respiratory Distress Syndrome (ARDS) [5][6]. Oxygen (O_2) is a gas that is required for metabolic processes [7]. All functional body processes rely on oxygen. The absence of oxygen causes the body's functional decline or even death. As a result, the most important and critical requirement for the body is oxygen [8][9]. The percentage level of oxygen-bound hemoglobin or oxyhemoglobin in the blood is known as oxygen saturation. Hemoglobin is the component of blood that binds oxygen and transports it to organs, tissues, and body cells [10]. There are two methods for measuring oxygen saturation in the blood: Blood Gas Analysis (BGA), which is a blood test taken through an artery, and pulse oximetry, which estimates the amount of oxygen in the blood by sending infrared rays to the blood vessels. The amount of light reflected by capillaries and the oxygen level in the blood is measured [11]–[13]. A normal heart rate ranges from 60 to 100 beats per minute. Meanwhile, normal SpO2 levels range from 95% to 100%. When the SpO2 level falls below 95%, it indicates a hypoxic condition or a lack of oxygen. Hypoxia can occur without causing any signs or symptoms in some cases (happy hypoxia) [14][15]. That is a condition in which the patient's body is suddenly deprived of oxygen while remaining comfortable and exhibiting no symptoms. As a result, knowing the COVID-19 patient's heart rate and oxygen saturation (SpO2) is critical [16]. People infected with COVID-19 will generally experience hypoxia, which causes shortness of breath. If treated too late, the patient will experience respiratory failure, organ failure, and eventually death [17][18]. Implementation of wearable devices for continuous monitoring is expected to influence health care in several ways [19]. Therefore it is necessary to monitor health conditions, especially monitoring the value of heart rate and oxygen saturation by utilizing IoT (Internet of Things) [20]. Monitoring symptoms and signs of illness is important for patients and the paramedics to diagnose the virus disease [21]. This could facilitate patient’s mobility and recovery during admission [22][23]. Moreover, the devices can result in improved health outcomes and can be used as a diagnostic tool in the identification of several diseases or clinical deterioration during admission [24][25][26]. As a result, it is necessary to monitor health conditions, particularly the values of heart rate and oxygen saturation, using IoT (Internet of Things) [20][27][28]. It is hoped that doctors, nurses, or families can help monitor the vital signs to take appropriate action [29][30]. In addition to notifications, monitoring that is not separated by distance is required so that monitoring can be carried out anywhere and at any time. With remote monitoring, the doctor or nurse does not have to monitor the patient directly at all times using only the doctor's or nurse's cellphone to see the BPM and SpO2 values from the patient [31]. In 2021, Pandu Arsy Filonanda from the Medical Electrical Engineering Poltekkes Of The Ministry of Health Surabaya conducted a bpm and temperature detection research designed to resemble a Smartband used on the Wrist as well as data sent to Android The device was in the form of a bracelet with an LCD from the T-Display TTGO ESP32 that will display the BPM value obtained from the SEN0203 sensor with data collection on the wrist and using non-contact infrared temperature MLX90614 so that the temperature obtained by the temperature sensor is not affected by the heat around the sensor. However, the tool's size was still too large due to the use of two sensors, SEN0203 and MLX90614 [32].

Based on the results of the problem identification above, the author will create a tool Smartband Monitoring BPM and SpO2 Based on IoT (Internet of Things) to reduce patients who are late to be treated due to undetected early symptoms of COVID-19, minimize infection due to direct contact with patients, or contact with medical devices that have been used to treat patients [33]. This tool is a development of a previous tool that displays BPM and SpO2 values using the MAX86141 sensor with data retrieval on the wrist with a smaller physical form, The use of tools is not affected by distance, and aims to help paramedics or families detect early symptoms of COVID-19, monitor conditions patients continuously, and reduce direct contact with patients to minimize COVID-19 disease transmission.

II. MATERIALS AND METHODS

The study is conducted as an experiment. In this study, the authors proposed an IoT-based Smartband monitoring BPM and SpO2 to measure BPM and SpO2 parameters which are not separated by distance from the IoT system. The materials and method will be explained in the following section.

A. DATA COLLECTION

BPM and SpO2 data were retrieved from 10 adult respondents, 5 male respondents, and 5 female respondents over the age of 18, with each respondent taking data 10 times using comparisons and the data retrieval time interval was every 5 seconds using the metronome application. The MAX86141 sensor is used in this study as a BPM and SpO2 sensor on the wrist. The voltage source is a 3.7v Lithium Battery [34]. The ESP32 TTGO T-Display incorporates a microcontroller, display, and WiFi module. Pulse oximetry is used as a comparison tool for BPM and SpO2 data. The Smartband module design can be seen in **FIGURE 1.**

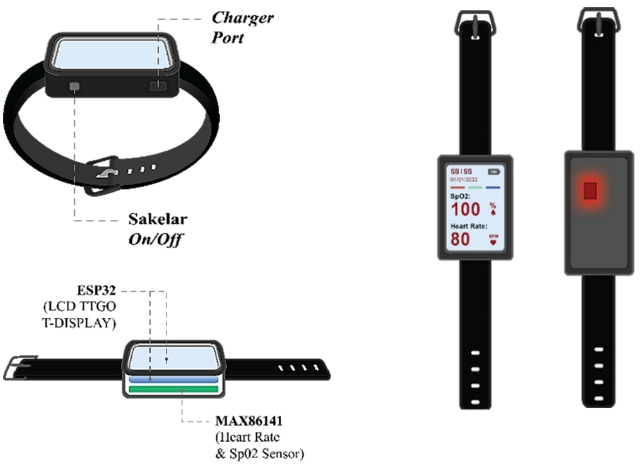


FIGURE 1. Smartband monitoring BPM and SpO2 based on IoT using the MAX86141 sensor and ESP32 TTGO T-Display module design

In this study, after the tool was completed, the module measurement results were compared to the following steps and the measurement process is carried out as in FIGURE 2:

1. The respondent activates the tool and secures it to the respondent's wrist by tightening the strap or rubber band to fit the size of the wrist.
2. To ensure optimal sensor performance, make sure the sensor's surface is in contact with the skin.
3. Respondents used pulse oximetry on their fingers as a comparison tool.
4. Using the metronome application, each respondent will collect 10 BPM and SpO2 data points at 5-second intervals.
5. After 10 seconds, the module will display the BPM SpO2 reading and compare it to the pulse oximetry reading.
6. Keep a record of each measurement result for data analysis.

FIGURE 2. The process of measuring BPM and SpO2 parameters using Smartband module design and pulse oximetry (Finger Pulse Oximeter General Care Model F02T)

The patient will be paired with a bracelet that already has a MAX86141 sensor that reads BPM and SpO2 data from the patient's wrist. The data reading from the MAX86141 sensor will be processed by the ESP32 TTGO T-Display microcontroller and displayed on the LCD from the ESP32 TTGO T-Display before being sent to the Blynk application on the smartphone device. If the patient's condition is abnormal, the Blynk application will send an email notification to the specified email address immediately. These steps can be viewed according to **FIGURE 3**.

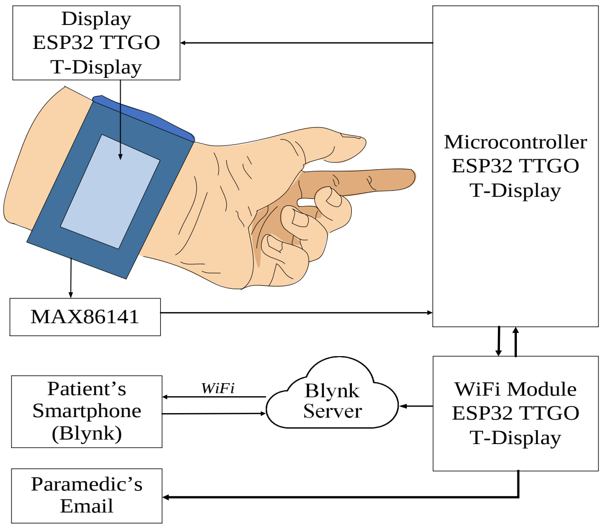


FIGURE 3. System Diagram Block. When the system starts working, Smartband detects BPM and SpO2 from the wrist. ESP32 TTGO T-Display will initialize the program and process the output results and display them on LCD, and send a notification if the result is abnormal

FIGURE 4 In the flowchart of the microcontroller when the start button is pressed, an initialization process begins, and the MAX86141 sensor begins to detect heart rate and oxygen saturation on the patient's wrist. The reflection method is used to measure heart rate and oxygen saturation in the wrist blood vessels, with infrared as a light source paired parallel to a photodiode as a light sensor. The photodiode's signal or change is the reflection of infrared light. The amount of light intensity received by the photodiode is converted into an electric current. The ESP32 TTGO T-Display, as a microcontroller, will process the data and calculate the heart rate (BPM) and oxygen saturation (SpO2) values based on the reflected light from infrared emitted into the veins on the wrist. After the value of the two parameters has been determined, it will be displayed as a number on the ESP32 TTGO T-LCD Display and sent to the Blynk application installed on the patient's smartphone via a Wi-Fi connection. When the patient's condition is abnormal or the oxygen saturation value (SpO2) is less than 95 percent and BPM is under 60 and more than 100, the Blynk application on the patient's smartphone will send notifications while sending monitoring data to the specified email address.

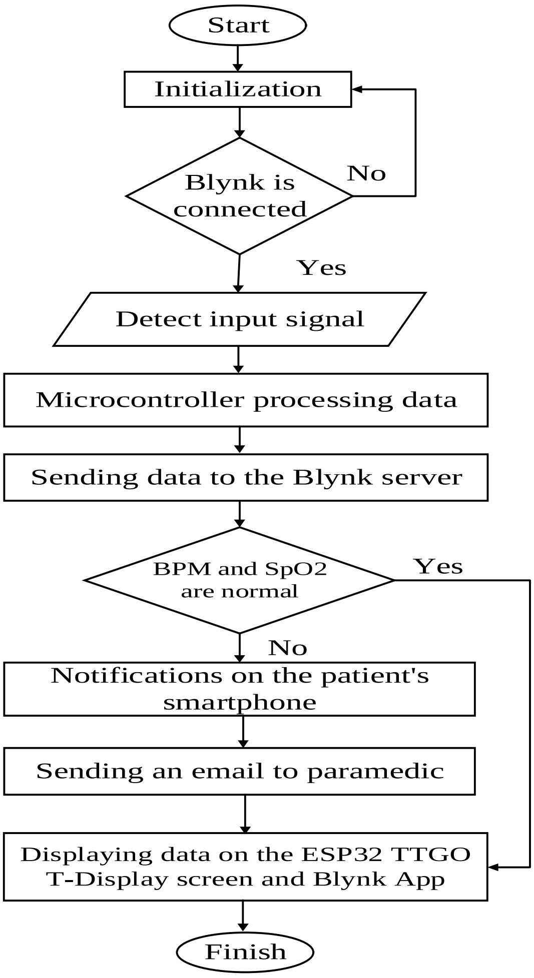


FIGURE 4. The flowchart of the system. The system begins by initializing and connecting to Blynk App. The sensor detects the input signal and the microcontroller process the data signal. The output sends to the Blynk server and displayed on ESP32 TTGO T-Display and Blynk. If the BPM and SpO2 are abnormal, the system will send a notification on the smartphone and an email.

B. DATA ANALYSIS

Measurements of each parameter, BPM, and SpO2 all were repeated 10 times. The average value of the measurement is obtained by using the mean or average by applying equation (1):

$$\bar{x} = \frac{x1+x2+\cdots+x}{n} \quad (1)$$

where $\bar{x}$ indicates the mean (average) value for n measurement, $x1$ indicates the first measurement, $x2$ shows the second measurement, and x indicates the n measurement. The standard deviation is a value that indicates the level (degree) of variation in a group of data or a standard measure of deviation from its mean. The standard deviation (SD) formula can be shown in equation (2):

$$S = \sqrt{\frac{\sum(x-\bar{x})^2}{(n-1)}} \quad (2)$$

where x indicates the amount of the desired values, $\bar{x}$ indicates the average of the measurement results, n shows the number of measurements. SD shows the resulted standard deviation, and n show the amount of measurement. The %error shows the error of the system. The lower value error is the difference between the mean of each data. The error can show the deviation between the standard and the design or model. The error formula is shown in equation (3).

$$\%e = \frac{(x-x_n)}{x_n} \times 100\% \quad (3)$$

where x_n is a value measured from the calibrator. The x is the value measured from the design.

III. RESULT

BPM and SpO2 data are taken from the comparison display, namely pulse oximetry, and compared with the values listed on the MAX86141 module's display. Each respondent collected BPM and SpO2 data with MAX86141 and pulse oximetry 10 times. The average value of BPM and SpO2 is then calculated and compared to the mean value of MAX86141 and pulse oximetry in 10 respondents. Data is presented graphically in TABLE 1, TABLE 2, FIGURE 5, and FIGURE 6.

TABLE 1.
The average BPM for 10 respondents (R) was 10 times data collection with MAX86141 and pulse oximetry

Subject	Average MAX86141 (BPM)	Average Pulse Oximetry (BPM)	Standard Deviation	Error (%)
R1	59.9	58.8	3.90	1,836
R2	79.4	84.9	3.92	6,927
R3	85.8	89	7.90	3,730
R4	64.7	65.7	5.98	1,546
R5	84.3	85.1	9.81	0,949
R6	100.9	102.5	7.29	1,586
R7	72.2	74.3	4.92	2,909
R8	86.7	87.7	10.15	1,153
R9	72.1	75.4	2.51	4,577
R10	82.3	84.7	3.86	2,916

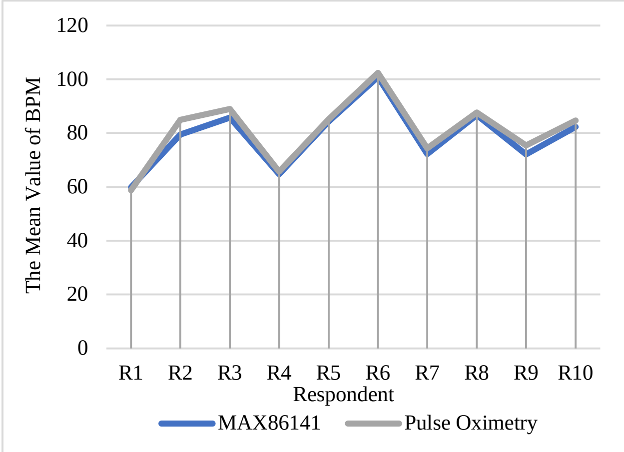


FIGURE 5. Graph mean value of BPM between MAX86141 and pulse oximetry

TABLE 2.
The average SpO2 for 10 respondents was 10 times data collection with MAX86141 and pulse oximetry

Subject	Average MAX86141 (%)	Average Pulse Oximetry (%)	Standard Deviation	Error (%)
R1	98.7	98.1	0.95	0,608
R2	99.1	97.9	0.32	1,211
R3	97.7	96.6	0.48	1,126
R4	98.9	96.4	0.74	2,528
R5	98.9	98.2	0.32	0,708
R6	94.6	96.4	0.52	1,903
R7	98.3	98.1	0.48	0,203
R8	99.1	98.7	0.32	0,404
R9	99.1	97.1	0.32	2,018
R10	95.8	97.5	0.79	1,775

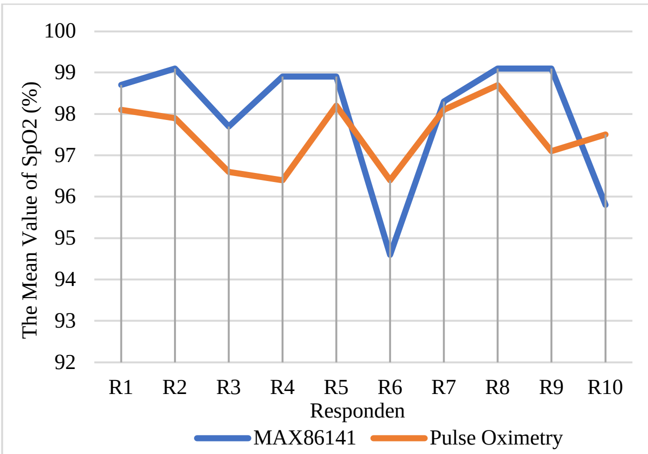


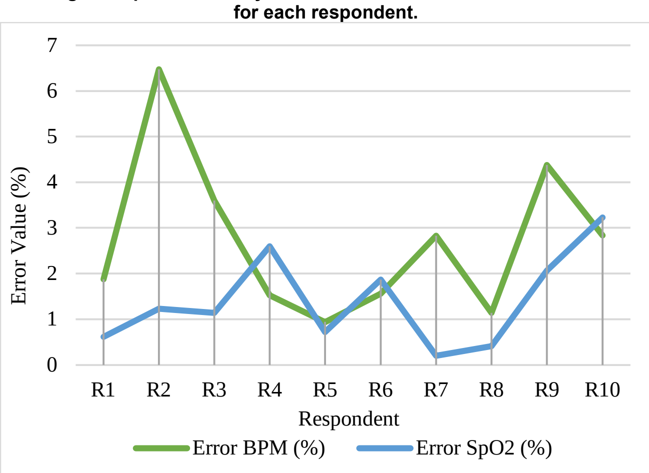
FIGURE 6. Graph mean value of SpO2 between MAX86141 and pulse oximetry

TABLE 2 and FIGURE 5 The error value and standard deviation can be calculated using the mean BPM and SpO2 value between MAX86141 and pulse oximetry. The smallest error value in BPM data is 0.94 percent, and the largest error value is 6.48 percent and producing an average error value of 2.76 percent. The smallest error value in SpO2 data is 0.20 percent, and the largest error value is 3.23 percent and producing an average error value of 1.41 percent. Nonlinearity in the BPM and SpO2 value in the module can be caused by the movement of the patient's hand and improper placement of the module on the patient's wrist

TABLE 3.
Error and standard deviation test of BPM and SpO2

Subject	BPM		SpO2	
	SD	Error (%)	SD	Error (%)
R1	3.90	1.87	0.95	0.61
R2	3.92	6.48	0.32	1.23
R3	7.90	3.60	0.48	1.14
R4	5.98	1.52	0.74	2.59
R5	9.81	0.94	0.32	0.71
R6	7.29	1.56	0.52	1.87
R7	4.92	2.83	0.48	0.20
R8	10.15	1.14	0.32	0.41
R9	2.51	4.38	0.32	2.06
R10	3.86	2.83	0.79	3.23
Average	**6.03**	**2.76**	**0.53**	**1.41**

FIGURE 7. Graph BPM and SpO2 parameters measurement error between the design and pulse oximetry. The measurement was conducted 10 times for each respondent.



IV. DISCUSSION

Data analysis is performed to determine the final result of the tool as well as the level of accuracy of the sensors used. Data will be collected from 10 respondents, with each respondent collecting data 10 times at a 5-second interval using the metronome application. The MAX86141 sensor's measurement results on the BPM and SpO2 parameters were compared to pulse oximetry. The BPM data has the smallest error of 0.94 percent and the largest error of 6.48 percent, while the SpO2 data has the smallest error of 0.20 percent and the largest error of 3.23 percent. The BPM and SpO2 values in the module are nonlinear, which can be caused by patient movement, differences in data collection location, and placement of the module on the patient's wrist.

In 2022, Muhammad Syaidul Alam from the Department of Computer Engineering at American International University-Bangladesh (AIUB) conducted a study titled An IoT Based Project on Patient Health Monitoring System [35]. The MAX30100 sensor is used as a BPM SpO2 sensor, the MLX90614 as a temperature sensor, the ESP8266 as a Wi-Fi module, a 3.7V lithium battery, and TP4016 charger module, an OLED display, and a breadboard in this tool. In comparison to this study, this Smartband device has several advantages, including the use of the ESP32 TTGO T-Display component, which can function as a microcontroller, display, and Wi-Fi module, reducing the use of tools and materials. Because the ESP32 TTGO T-Display is already connected to the battery, charging to a 3.7V lithium battery without the use of a charger module is possible. The MAX86141 sensor measurement results are directly displayed on the screen of the ESP32 TTGO T-Display, with no additional OLED. The tool is more portable and convenient, allowing it to be carried anywhere. The tool has time and date information without relying on the RTC module, but rather on a Wi-Fi connection.

After the analysis, this tool still has flaws, such as the measurement results on the module lacking graphics and the box size remaining too large, causing the measurement value to be unstable if the patient's wrist moves.

The results of the study on the above tool, with the design of a portable tool, the connection during monitoring activities are not separated by distance, and the results can be monitored on Blynk and there are abnormal notifications in email, are expected to have implications in increasing the ease and efficiency of BPM and SpO2 monitoring activities because this can certainly improve the quality of public health services, particularly during the COVID-19 pandemic.

V. CONCLUSION

The purpose of this study is to create a device on the patient's wrist that can monitor BPM and SpO2 in real-time and is not affected by distance, as well as provide notifications on smartphones and emails when the patient's condition is abnormal. BPM and SpO2 data were retrieved from 10 adult respondents, 5 male respondents, and 5 female respondents over the age of 18, with each respondent taking data 10 times using comparisons and the data retrieval time interval was every 5 seconds using the metronome application. According to the tool testing results, BPM has the smallest error of 0.94 percent and the largest error of 6.48 percent, whereas SpO2 has the smallest error of 0.20 percent and the largest error of 3.23 percent. It is hoped that this tool will assist medical personnel or families in monitoring the patient's condition so that they can take appropriate action and reduce direct contact with patients. Further research can be done by adding measurement results in graphic form, reducing the size of the box, making it more comfortable to use and ensuring that the value is not affected by the movement of the patient's wrist, and making the measurement value much more stable.

REFERENCES

[1] N. Bin Ahmed, S. Khan, N. A. Haque, and M. S. Hossain, "Pulse Rate and Blood Oxygen Monitor to Help Detect Covid-19: Implementation and Performance," in *2021 IEEE International IOT, Electronics and Mechatronics Conference (IEMTRONICS)*, Apr. 2021, no. May, pp. 1–5. doi: 10.1109/IEMTRONICS52119.2021.9422520.

[2] M. S. T. P. Sahrul, Triwiyanto, and Torib Hamzah, "Patient Monitor for SpO2 and Temperature Parameters," *J. Electron. Electromed. Eng. Med. Informatics*, vol. 1, no. 2, pp. 7–12, Oct. 2019, doi: 10.35882/jeeemi.v1i2.2.

[3] A. S. Utomo, E. H. P. Negoro, and M. Sofie, "MONITORING HEART RATE DAN SATURASI OKSIGEN MELALUI SMARTPHONE,"

Simetris J. Tek. Mesin, Elektro dan Ilmu Komput., vol. 10, no. 1, pp. 319–324, Apr. 2019, doi: 10.24176/simet.v10i1.3024.

[4] H. Ghandeharioun, “Automatic Home-based Screening of Obstructive Sleep Apnea using Single Channel Electrocardiogram and SPO2 Signals,” *Int. J. Artif. Intell. Appl.*, vol. 12, no. 06, pp. 47–63, Nov. 2021, doi: 10.5121/ijaia.2021.12605.

[5] A. B. Gopal *et al.*, “Silent hypoxia in COVID-19: a gut microbiota connection,” *Curr. Opin. Physiol.*, vol. 23, p. 100456, 2021, doi: 10.1016/j.cophys.2021.06.010.

[6] P. Sirohiya *et al.*, “A Correlation Analysis of Peripheral Oxygen Saturation and Arterial Oxygen Saturation Among COVID-19 Patients,” *Cureus*, vol. 10, no. April, pp. 5–12, Apr. 2022, doi: 10.7759/cureus.24005.

[7] J. Baut, “Estimation of SpO2 at the Upper Arm,” vol. 10, no. December, pp. 5–12, 2020, doi: 10.13140/RG.2.2.25701.42726.

[8] Siswanto *et al.*, “Possible silent hypoxemia in a COVID-19 patient: A case report,” *Ann. Med. Surg.*, vol. 60, no. November, pp. 583–586, 2020, doi: 10.1016/j.amsu.2020.11.053.

[9] A. Madan, “Correlation between the levels of SpO2 and PaO2,” no. May 2017, pp. 10–12, 2021, doi: 10.4103/lungindia.lungindia.

[10] N. K. Rauniyar, S. Pujari, and P. Shrestha, “Study of Oxygen Saturation by Pulse Oximetry and Arterial Blood Gas in ICU Patients : A Descriptive Cross-sectional Study,” no. October 2020, pp. 3–8, 2021, doi: 10.31729/jnma.5536.

[11] A. Sarkar, V. Sinha, S. A. Mandlik, and J. Kathirvelan, “NON-INVASIVE BLOOD OXYGEN SATURATION MONITORING (SpO2) USING TRANSMITTANCE for PULSE OXIMETER,” *Biomed. Eng. - Appl. Basis Commun.*, vol. 31, no. 6, pp. 1–9, 2019, doi: 10.4015/S1016237219500431.

[12] A. John, K. K. Nundy, B. Cardiff, and D. John, “SomnNET: An SpO2 Based Deep Learning Network for Sleep Apnea Detection in Smartwatches,” in *2021 43rd Annual International Conference of the IEEE Engineering in Medicine & Biology Society (EMBC)*, Nov. 2021, no. November, pp. 1961–1964. doi: 10.1109/EMBC46164.2021.9631037.

[13] I. B. Aguirregomezcorta, V. Blazek, and S. Leonhardt, “Learning about reflective PPG for SpO2 determination using Machine Learning,” vol. 7, no. 2, pp. 33–36, 2021, doi: 10.1515/cdbme-2021-2009 1.

[14] E. M. J. Durlinger *et al.*, “Hyperoxia: At what level of SpO2 is a patient safe? A study in mechanically ventilated ICU patients,” *J. Crit. Care*, vol. 39, pp. 199–204, 2017, doi: 10.1016/j.jcrc.2017.02.031.

[15] A. Patekar and U. Kawalkar, “SpO2 Monitoring With the Home-Based COVID care Kit for Home Isolated COVID Patients,” no. November, pp. 18–20, 2021, doi: 10.1177/10105395211058290.

[16] S. Z. Tachiyat, A. R. Imanda, and M. A. Tholib, “Design and build an IoT-based SpO2 Heart Rate Monitoring System and Body Temperature for COVID-19 Patients,” *J. Pendidik. Fis. dan Keilmuan*, vol. 6, no. 2, p. 120, 2020, doi: 10.25273/jpfk.v6i2.7952.

[17] S. Sun, Y. Huang, and X. Yin, “Using admission SpO2 and ROX index predict outcome in patients with COVID-19,” *Am. J. Emerg. Med.*, no. July, p. 160340, 2021, doi: 10.1016/j.ajem.2021.08.055.

[18] M. F. A. Fikri, D. P. Kartikasari, and A. Bhawiyuga, “Implementation of Oxygen Saturation Sensor Data Acquisition Based on Bluetooth Low Energy Protocol,” *Kinet. Game Technol. Inf. Syst. Comput. Network, Comput. Electron. Control*, vol. 4, no. 3, 2021, doi: 10.22219/kinetik.v6i3.1305.

[19] M. Weenk, S. J. Bredie, M. Koeneman, G. Hesselink, H. Van Goor, and T. H. Van De Belt, “Continuous monitoring of vital signs in the general ward using wearable devices: Randomized controlled trial,” *J. Med. Internet Res.*, vol. 22, no. 6, pp. 1–11, 2020, doi: 10.2196/15471.

[20] M. A. Zaltum, M. S. Ahmad, A. Joret, and M. M. Abdul, “Design and Development of a portable Pulse Oximetry system,” *Pulse*, vol. 05, no. 03, pp. 37–44, 2010.

[21] C. C.-19 D. T. A. G. Struyf T, Deeks JJ, Dinnes J, Takwoingi Y, Davenport C, Leeflang MMG, Spijker R, Hooft L, Emperador D, Domen J, Horn SRA, Van den Bruel A, “care or hospital outpatient settings has COVID-19 (Review),” vol. 19, 2021, doi: 10.1002/14651858.CD013665.pub2.www.cochranelibrary.com.

[22] A. M. Chan, N. Ferdosi, and R. Narasimhan, “Ambulatory respiratory rate detection using ECG and a triaxial accelerometer,” *Proc. Annu. Int. Conf. IEEE Eng. Med. Biol. Soc. EMBS*, vol. 79, pp. 4058–4061, 2013, doi: 10.1109/EMBC.2013.6610436.

[23] R. Sahandi, S. Noroozi, G. Roushan, V. Heaslip, and Y. Liu, “Wireless technology in the evolution of patient monitoring on general hospital wards,” *J. Med. Eng. Technol.*, vol. 34, no. 1, pp. 51–63, 2010, doi: 10.3109/03091900903336902.

[24] E. C. Geoff Appelboom1 *et al.*, “Smart wearable body sensors for patient self-assessment and monitoring.,” *Arch. Public Heal.*, vol. 72, no. 28, pp. 1–9, 2014.

[25] S. Majumder, T. Mondal, and M. J. Deen, “Wearable sensors for remote health monitoring,” *Sensors (Switzerland)*, vol. 17, no. 1, 2017, doi: 10.3390/s17010130.

[26] M. Cardona-Morrell, M. Prgomet, R. M. Turner, M. Nicholson, and K. Hillman, “Effectiveness of continuous or intermittent vital signs monitoring in preventing adverse events on general wards: a systematic review and meta-analysis,” *Int. J. Clin. Pract.*, vol. 70, no. 10, pp. 806–824, 2016, doi: 10.1111/ijcp.12846.

[27] Y. Yuliza and H. Pangaribuan, “IoT-based digital stove design,” *J. Teknol. Elektro*, vol. 7, no. 3, pp. 187–192, 2016, doi: 10.22441/jte.v7i3.897.

[28] A. Marina, H. K. Ilman, F. Febi, A. E. Muhammad, and I. Muhammad, “Studi Perbandingan Platform Internet of Things (IoT) untuk Smart Home Kontrol Lampu Menggunakan NodeMCU dengan Aplikasi Web Thingspeak dan Blynk,” *J. Fidel.*, vol. 2, no. 1, pp. 59–78, 2020.

[29] J. Xue *et al.*, “Design of a wearable device for monitoring SpO2 continuously,” *Proc. - 2015 IEEE 12th Int. Conf. Ubiquitous Intell. Comput. 2015 IEEE 12th Int. Conf. Adv. Trust. Comput. 2015 IEEE 15th Int. Conf. Scalable Comput. Commun. 20*, pp. 1253–1257, 2016, doi: 10.1109/UIC-ATC-ScalCom-CBDCom-IoP.2015.227.

[30] S. B. Patil and A. M. Sattikar, “IoT Based SPO2 and Temperature Monitoring Using Arduino Mega and GSM,” vol. 10, no. March, pp. 5–12, 2022.

[31] A. Al-Naji, G. A. Khalid, J. F. Mahdi, and J. Chahl, “Non-Contact SpO2 Prediction System Based on a Digital Camera,” *Appl. Sci.*, vol. 11, no. 9, p. 4255, May 2021, doi: 10.3390/app11094255.

[32] P. A. Filonanda, I. D. G. H. WISANA, and P. C. NUGRAHA, “Smart-band BPM and Temperature Based on Android Using Wi-Fi Communication,” *J. Teknokes*, vol. 14, no. 2, pp. 62–67, 2021, doi: 10.35882/teknokes.v14i2.3.

[33] D. Ekiz, Y. S. Can, Y. C. Dardagan, and C. Ersoy, “Can a Smartband be Used for Continuous Implicit Authentication in Real Life,” *IEEE Access*, vol. 8, no. May, pp. 59402–59411, 2020, doi: 10.1109/ACCESS.2020.2982852.

[34] F. A. Perdana, “Lithium Battery,” *INKUIRI J. Pendidik. IPA*, vol. 9, no. 2, p. 113, 2021, doi: 10.20961/inkuiri.v9i2.50082.

[35] M. S. Alam, “An IoT Based Project on Patient Health Monitoring System,” vol. 10, no. May, pp. 5–12, 2022, doi: 10.13140/RG.2.2.19960.72967.

APPENDIX

Listing Program: https://docs.google.com/document/d/1Wtz-SljcAE1yErRhTKaDvmJDttFTsR0u/edit?usp=sharing&ouid=108696089362741987293&rtpof=true&sd=true

Schematic:
https://docs.google.com/document/d/1mzMdYb6xXxnBQBM0GXOym4-ZtE63ESRE/edit?usp=sharing&ouid=108696089362741987293&rtpof=true&sd=true