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Spo2 Analysis on Development of IoT-Based Lung Function and Spo2 Measuring Device

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ABSTRACT Pulmonary dysfunction is a widespread issue, particularly in developing nations. It encompasses restrictive, obstructive, and mixed pulmonary function disorders that lead to a decrease in vital lung capacity, an increase in functional residual capacity, and a decline in blood oxygen concentration and saturation. This study aims to combine oximetry and spirometry into a single device, using the Internet of Things (IoT) technology to display results via a smartphone app. The focus is on analyzing oxygen saturation, with normal levels ranging from 96% to 100% in adults, alongside a heart rate of 60-100 beats per minute. The MAX30102 sensor measures oxygen saturation, and the Arduino Pro Mini and D1 Mini ESP32 microcontrollers process data. The Android-based app, developed using Kodular platform, integrates a MySQL database and connects to the device module via Wi-Fi. Ten respondents underwent five measurements, revealing an average error of ±0.88% for oxygen saturation (SpO_2) and ±2.82% for heart rate measurements. The average data loss rate during transmission was ±0.66% for SpO_2 and ±0.89% for heart rate. These findings highlight existing errors in the module. The research aims to facilitate remote health monitoring for healthcare professionals, improving accessibility and healthcare provision.

INDEX TERMS Oximetry, MAX30102, SpO_2, BPM. Kodular platform.

I. INTRODUCTION

Pulmonary function disorders pose a global health challenge, particularly in developing countries. These disorders, categorized as restrictive, obstructive, or mixed, are diagnosed through pulmonary function tests using a spirometry [1][2][3]. Respiratory tract narrowing, as seen in conditions like asthma, leads to bronchial obstruction and muscle spasms, resulting in breathing difficulties. This obstruction affects lung function parameters, including vital lung capacity and residual volume [4][5]. Asthma patients often experience symptoms such as shortness of breath due to airway narrowing caused by hyperreactivity, leading to bronchospasm, inflammation, mucosal edema, and increased mucus production. Consequently, there is a decrease in vital lung capacity and an increase in residual volume, leading to decreased oxygen concentration in the blood and lower oxygen saturation levels [6][7]. Oxygen saturation (SpO_2), measured using oximetry, indicates the percentage of oxygen carried by hemoglobin. In conclusion, the condition of the lungs directly influences the level of oxygen saturation in the blood [8][9]. Monitoring oxygen saturation is crucial in assessing respiratory health and managing pulmonary disorders effectively. By analyzing these levels, healthcare professionals can gain valuable insights into the severity and progression of these conditions, enabling appropriate treatment strategies[10][11].

In recent years, several studies have been conducted to explore the relationship between pulmonary health and various factors. Andhika Ariyanto's study in 2019 make an analysis of vital pulmonary capacity with hemoglobin levels and oxygen saturation in conventional electrical smokers shed light on the impact of cigarette smoking on lung health. The findings indicated a decrease in pulmonary vital capacity in both conventional and electronic cigarette smokers, with lower oxygen saturation levels observed in conventional cigarette smokers compared to electronic cigarette users [12]. However, it is worth noting that this study focused solely on vital capacity, neglecting other essential parameters for assessing lung health. Vinay Kumar A. et al. conducted a study of importance to spirometry, pulse oximetry and hematocrit in chronic obstructive pulmonary disease. Approximately 40% of the cases were identified as

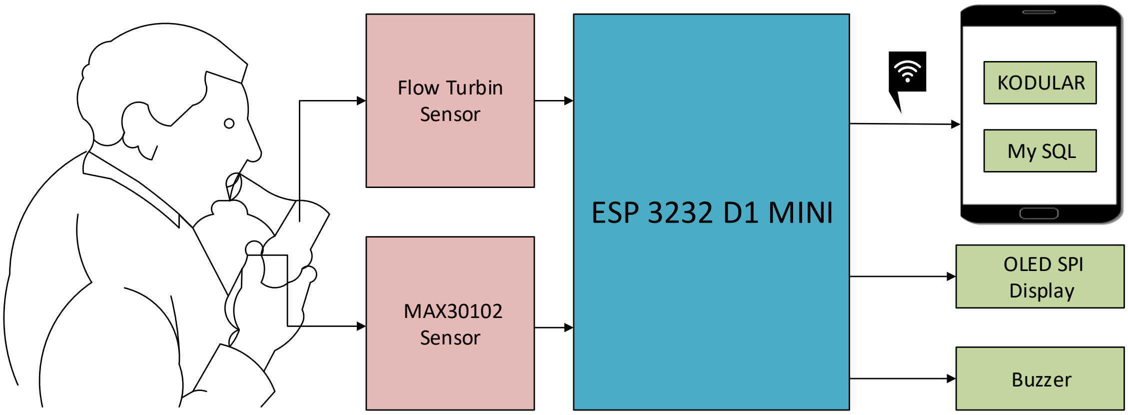


FIGURE 1. Block diagram of the system with a turbine flow sensor for pulmonary function measurement and a MAX30102 sensor for oxygen saturation measurement.

stage III disease. Among these cases, computerized spirometry proved to be the most effective diagnostic tool for detecting and evaluating the severity of the disease. As the disease's severity and duration increased, the patients were more susceptible to developing complications such as hypoxia and polycythemia. Within the current study, 8 patients were identified to have hypoxia, which was assessed using a pulse oximetry, pulse oximetry also useful in monitoring the oxygen therapy during management [13]. Although the study highlighted the importance of oxygen saturation, it did not specify the lung health parameters utilized for the assessment. I Putu Anna Andika's work involved the development of a portable pulse oximetry device for measuring blood oxygen saturation using MAX30102 sensor. In this research, the investigators assessed the SpO_2 level and heart rate of ten adult participants chosen at random. The obtained data was then compared to readings obtained from standard measuring devices. The SpO_2 measurement displayed an error margin of 0.82%, while the error margin for beats per minute (BPM) was 0.84%. Based on the measurement outcomes, this instrument demonstrated effective performance and suitability for use. However, a notable drawback of this module is its susceptibility to significant error values when there a finger movement during the measurement process [14].

These studies collectively contribute to our understanding of pulmonary health and its assessment. They emphasize the importance of comprehensive evaluation, incorporating multiple parameters to ensure accurate monitoring and diagnosis. Building upon these findings, our research aims to revolutionize pulmonary health monitoring by integrating IoT technology and providing a user-friendly smartphone application for remote assessment of lung function and oxygen saturation [15][16]. In this article, we present a groundbreaking approach to pulmonary health monitoring by combining oximetry and spirometry into a unified device. Leveraging the power of the Internet of Things (IoT), we enable data collection, analysis, and display through a user-friendly smartphone application. By seamlessly integrating these essential measurements, healthcare professionals can gain comprehensive insights into patients' respiratory health, fostering more accurate diagnoses and tailored treatment plans.

This article focuses on the analysis of sensor readings oxygen saturation values and heart rate, as well as the capability of IoT transmission. Normal oxygen saturation levels in adults typically range between 96% and 100%, accompanied by a heart rate within the range of 60 to 100 beats per minute. To ensure precise measurements, we employ the MAX30102 sensor for oxygen saturation assessment [17][18]. Our developed Android-based application with a database, establishes a secure and intuitive platform for healthcare professionals to remotely monitor patients' pulmonary health. Through a Wi-Fi connection, the application seamlessly collects and displays accurate measurements of oxygen saturation and heart rate, empowering healthcare providers with timely and actionable insights [4]. To evaluate the performance of our integrated monitoring system, we conducted measurements on a sample of ten randomly selected respondents. Each participant underwent five measurements, allowing for a comprehensive assessment of accuracy and reliability. By analyzing the average error values and data loss rates, we shed light on the system's strengths and areas for improvement.

II. MATERIALS AND METHODS

A. EXPERIMENTAL SETUP

In this study, the measurement of Spirometry and Oximetry requires the patient to insert a funnel or mouthpiece into their mouth and blow air as per the measurement procedure. Simultaneously, the patient places their finger on the MAX30102 sensor to measure SpO_2 and BPM. Following this, the sensor data is received by a microcontroller, specifically the NodeMCU ESP8266, and then displayed on the SPI OLED LCD ST7789. The data values are subsequently transmitted wirelessly through a Wi-Fi connection to an IoT display, which is a smartphone application developed using Kodular platform [19]. The application includes a storage database implemented with MySQL[20].

1) MATERIALS AND TOOL

This research utilizes the fingertip Model A2 brand, a comparative pulse oximetry, to measure SpO_2 and BPM using the MAX30102 sensor. The data is processed by the NodeMCU ESP8266 [21] microcontroller and displayed on the SPI OLED LCD ST7789. It is then transmitted via Wi-Fi to an Android application created with Kodular platform, which includes a MySQL database.

2) EXPERIMENT

In this research, data was collected from 10 adult respondents were selected randomly, consisting of 1 woman and 9 men, within an age range of 19-22 years and a height range of 160-175 cm. The experiment was conducted with the respondents in a sitting position, and it was repeated 5 times for each respondent. The respondent placing their fingers on the device module and the comparative device. The obtained data was displayed on the OLED LCD and transmitted via Wi-Fi to the Android application. A comparison was made between the device module's display, the application's displayed data, and the comparative device's results.

B. THE DIAGRAM BLOCK

Following is the block diagram of the system in this research, as depicted in FIGURE 1. It is explained that to measure Spirometry and Oximetry, the patient needs to place a funnel or mouthpiece into the mouth and blow air according to the measurement procedure. At the same time, the patient's finger is positioned on the MAX30102 sensor to measure SpO_2 and BPM. Afterward, the data from the sensor will enter the microcontroller, specifically the Arduino Pro Mini and D1 Mini ESP32, and then be displayed on the SPI OLED LCD ST7789. Subsequently, the data values will be wirelessly transmitted using a Wi-Fi connection to an IoT display, which is an application on a smartphone created using Kodular platform software. The application is equipped with a storage database using MySQL. Additionally, there is a Buzzer that functions as an indicator for the device.

C. THE FLOWCHART

The following is a flowchart of the device module that has been created, specifically detailing the operation of the MAX30102 sensor. The comprehensive flowchart depicted in FIGURE 2. provides a clear overview of the operational sequence of the oximetry module. Upon powering on the device, the microcontroller program initiates an initialization process to ensure proper functioning. Subsequently, a Wi-Fi connection is established between the device module and the Android application, which has been developed using Kodular platform [19][22]. Once the connection is established, the Buzzer emits a sound, indicating successful device connectivity. At this stage, the user is prompted to position their finger on the MAX30102 sensor.[23][24] The Buzzer will sound again, indicating that the sensor is actively detecting and reading the values of SpO_2 and BPM in the blood. It is important for the user to maintain a steady finger position until the Buzzer sounds once more, signifying that the sensor has successfully captured the SpO_2 and BPM readings.

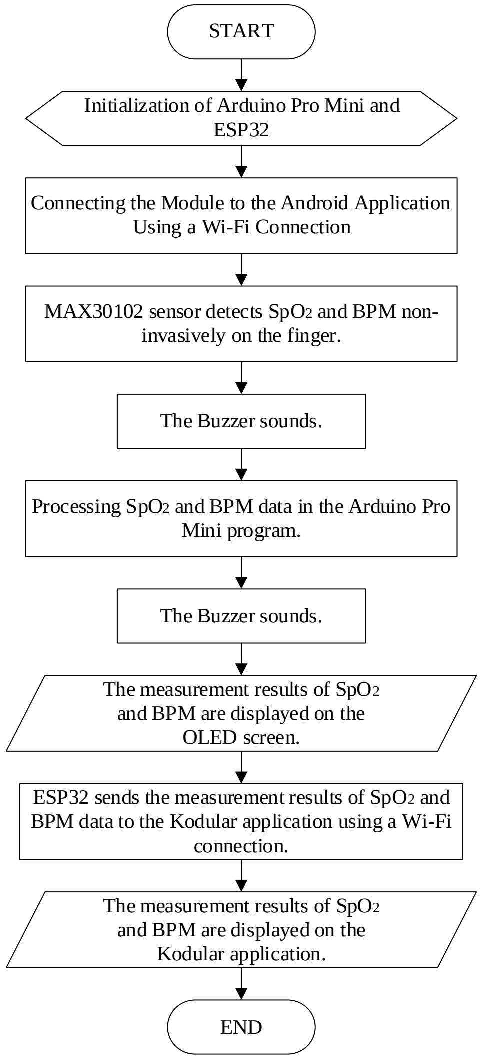


FIGURE 2. **Flowchart operation system MAX30102 sensor of module**

The data obtained from the MAX30102 sensor is then processed within the Arduino Pro Mini program [4][23] The processed data is subsequently transferred to the D1 Mini ESP32 program for further handling. From the ESP32, the data values are simultaneously sent to both the OLED LCD display located on the device module and the Android application running on the connected smartphone via Wi-Fi.

The Android application serves as a centralized hub for monitoring and storing the data. Leveraging the power of a MySQL database, the application efficiently stores each examination or measurement performed. [25][20] This ensures that the recorded data remains accessible for future reference and analysis. Moreover, the application offers the functionality to download the stored data in the form of an xlsx file. This flexibility allows users to access their health data not only through the application but also on other devices such as smartphones, PCs, or laptops.

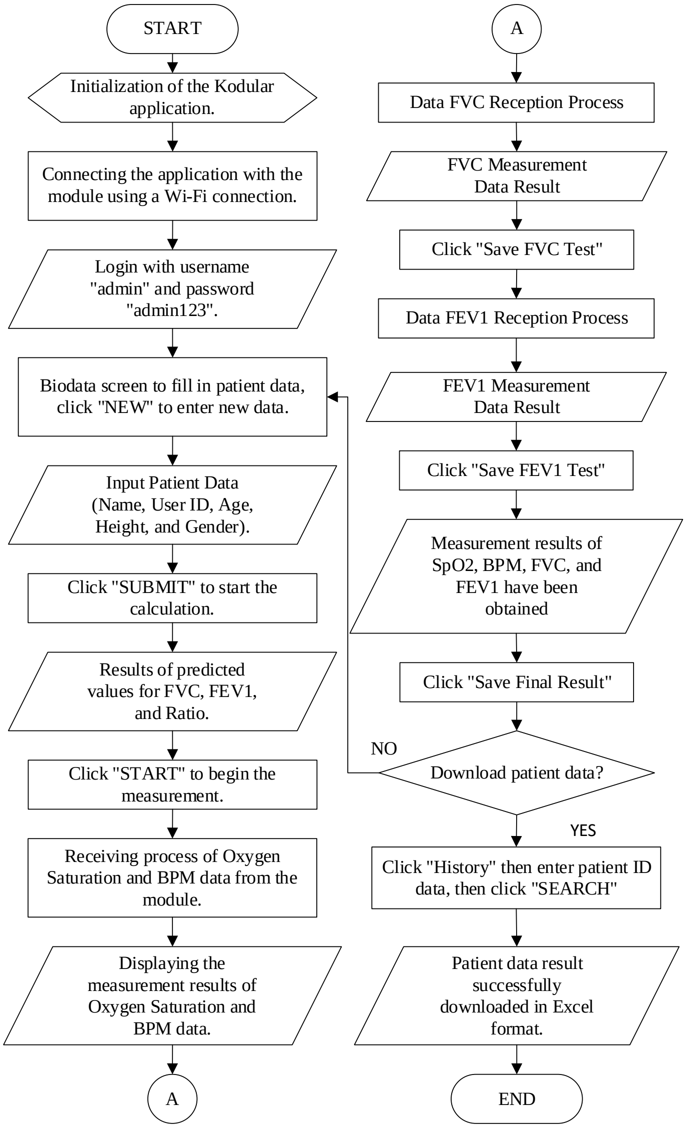


FIGURE 3. Flowchart operation system of android application

In FIGURE 3. when the application is turned on, the initial initialization process occurs. Then, the application establishes a connection with the device module using a Wi-Fi connection. Next, a login page will appear, enter the username "admin" and password "admin123". After that, the biodata page will appear to fill in patient or respondent data, click "NEW" to enter new patient data. Enter the patient's data such as name, user ID, age, height, and select gender. Then, click "SUBMIT" to display the calculation results of predicted values for FVC, FEV1, and ratio for pulmonary function prediction. To start the measurement, click "START" and perform the measurement on the device module by placing a finger on the MAX30102 sensor. The application will then receive data from the D1 Mini ESP32 in the device module, and the data will be displayed on the monitoring page. Once the data for SpO_2 and BPM has been collected, proceed with the pulmonary function testing, namely FVC and FEV1. FVC and FEV1 measurements are performed alternately. After obtaining the FVC result, the data needs to be saved by clicking "Save FVC Test", then FEV1 measurement can be performed, and the result can be saved again by clicking "Save FEV1 Test". Once all the measurement results are obtained, click "Save Final Results". The data will be stored in the database system. To download the saved data, click the "History" page, enter the patient's ID data, then click "SEARCH" and download the data in the form of an Excel file (xlsx). If you want to perform a new measurement, go to the biodata page and click "NEW" to enter new patient data, and then proceed with the next measurement.

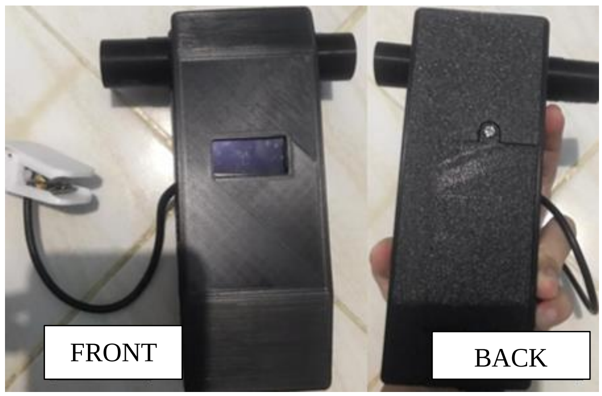


FIGURE 4. The front and back side of the module

FIGURE 5. Design of Android Application named SpirOxi, made by Kodular Platform

D. DESIGN OF MODULE

In FIGURE 4. It show the results of the module design are shown in the external appearance. On the front side, there is an OLED LCD screen and a space for the MAX30102 sensor to measure SpO_2 and BPM. On the back side, there is a cover for the battery. Additionally, there are two openings or funnels for the flow turbine sensor. The left side serves as the air input or the funnel placed near the patient's or respondent's mouth, while the right side serves as the air output only. A disposable mouthpiece will be added to the input funnel during measurements. Inside, there are the Arduino Pro Mini and D1 Mini ESP32 microcontroller circuits, as well as the flow turbine sensor for pulmonary function measurement, the MAX30102 sensor for SpO_2 and BPM measurement, a Buzzer circuit as an indicator, and a battery circuit as the module's power supply. In FIGURE 5. it shows of the design of the Android application created using Kodular platform. This application is equipped with a MySQL database [25][20]. The application is named SpirOxi.

E. Data Analysis

The first data analysis step to be performed is to calculate the average value of measurements on the module box, comparison device, and values displayed on the Android application for each respondent. The average value formula is in Eq. (1):

$$X = \frac{X1+X2+\cdots+Xn}{n} \quad (1)$$

Where X denotes the mean for the measurements, X_1 denotes the first measurements, X_2 denotes the second measurements, and Xn denotes n measurements. After that, from the data, calculate the standard deviation value for each respondent. The formula is shown in Eq. (2) :

$$s = \sqrt{\frac{\sum y^2 - \frac{(\sum y)^2}{n}}{n-1}} \quad (2)$$

Where, S denotes the standard deviation of the data, N denotes the number of data points, X denotes the desired value. Then, calculate the error value between the module box and the comparison device to determine the percentage of sensor reading error compared to the reference tool used. The formula is shown in Eq. (3) :

$$Error\ \% = \frac{Comparison\ Device - Module\ Box}{Comparison\ Device}\ x\ 100\% \quad (3)$$

Next, calculate the data loss value between the module box and the values displayed on the Android application to determine the transmission capability. The formula is shown in Eq. (4) :

$$Lost\ Data = \frac{Module\ Box - Android\ Application}{Module\ Box}\ x\ 100\% \quad (4)$$

Where, comparison device measurements is the measurements data that displayed on the comparison device is the oximetry, module box measurements is the measurements data that displayed on the module box and Android Application measurements is the measurements data that sent from module box and then displayed on the android application in smartphone.

III. RESULT

In this study, the measurement of oxygen saturation (SpO_2) and heart rate per minute (BPM) was conducted on 10 adult respondents (>19 years old), consisting of 1 woman and 9 men, selected randomly, within an age range of 19-22 years and a height range of 160-175 cm. The experiment was conducted with the respondents in a sitting position, and it was repeated 5 times for each respondent. The respondent placing their fingers on the device module and the comparison device.

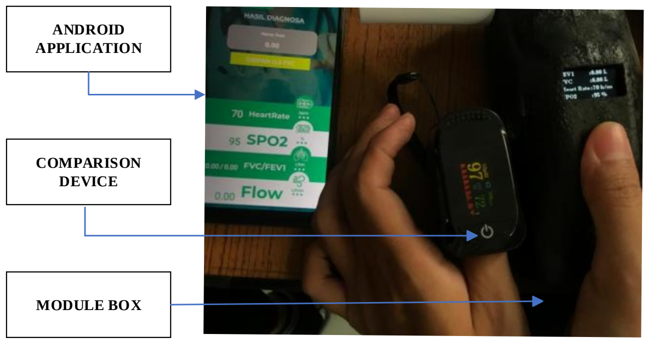


FIGURE 6. **Measurements of Android Application, Comparison Device and Module Box**

A) Steps in data collection:

To measure oxygen saturation (SpO_2) and heart rate (BPM), place the right finger on the device module and the other right finger on the reference device. Wait for the buzzer to sound, indicating that the sensor is detecting oxygen saturation (SpO_2) and heart rate (BPM). The buzzer will sound again when the SpO_2 and BPM data have been obtained. The acquired data will be displayed on the OLED LCD and then transmitted via Wi-Fi connection to the developed Android application. Compare the results displayed on the OLED LCD module, the transmitted and displayed data in the application, and the reference device, as shown in FIGURE 6. Then calculate the error value and the lost data value from the obtained data. Analyze the data and the calculated results afterward.

B) Results of Oxygen Saturation Measurement

The following are the table results of oxygen saturation measurement data from comparison device, modul box, android application, calculation of data error and calculation of lost data.

TABLE 1
Results Data of Oxygen Saturation Measurement

RESPONDEN	Average Values of Oxygen Saturation Measurements (%)			ERROR (%)	LOST DATA (%)
	COMPARISON DEVICE	MODULE BOX	ANDROID APLICATION		
1	98.2±0.83%	97.8±0.83%	95.8±1.64%	±0.20%	±2.04%
2	97.8±0.83%	97.2±0.83%	95.8±1.48%	±0.82%	±1.24%
3	97.6±1.14%	96.2±1.3%	95.6±1.14%	±1.43%	±0.62%
4	97.4±1.51%	97.2±0.83%	96.6±1.14%	±0.21%	±0.62%
5	97.4±0.89%	96.6±1.51%	95.8±1.3%	±0.82%	±0.83%
6	97.2±0.83%	96.2±1.3%	96.4±1.34%	±1.03%	±0.21%
7	96.8±2.16%	94.8±2.38%	94.2±2.48%	±2.07%	±0.63%
8	97.2±1.64%	95.8±2.16%	96.2±1.78%	±1.44%	±0.42%
9	97.2±1.3%	96.2±1.48%	95.8±1.48%	±1.03%	±0.42%
10	96.6±1.67%	96.8±1.48%	96.2±1.3%	±0.62%	±0.21%
AVERAGE				±0.88%	±0.66%

TABLE 1. shows the average measurement results between the device module, the comparison device, and the values transmitted to the application from 10 adult respondents (>19 years old), with data collection performed 5 times for each respondent. From the obtained data, the calculation of error values between the device module and the comparison device is conducted to determine if the measurement results from the device module are consistent with the comparison device. The overall calculation of error values between the module and the comparison device yields ±0.88%, indicating that the SpO_2 readings from the device module are not significantly different from the results of the pulse oximetry, which serves as the comparison device. Subsequently, calculations are conducted to determine the lost data between the data in the device module and the data transmitted to the Android application, in order to assess if the data from the device module can be successfully transmitted to the application via the Wi-Fi network. The calculation reveals a lost data value of ±0.66%, indicating that the SpO_2 measurement data from the device module to the application can be transmitted adequately.

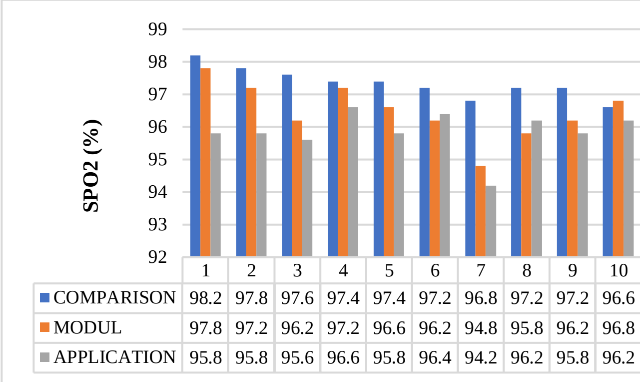


FIGURE 7. Average Values of Oxygen Saturation Measurements on Comparison Device, Module Box, and Android Application

In FIGURE 7. the graph and average values of the SpO_2 measurements from 10 respondents are shown for the device module, the comparison device, and the data displayed in the application. From the average data, differences in the measurement results can be observed between the module, the comparison device, and the data transmitted to the application.

C) Results of Heart Rate Measurements

The following are the table results of heart rate measurement data from comparison device, module box, android application, calculation of data error and calculation of lost data.

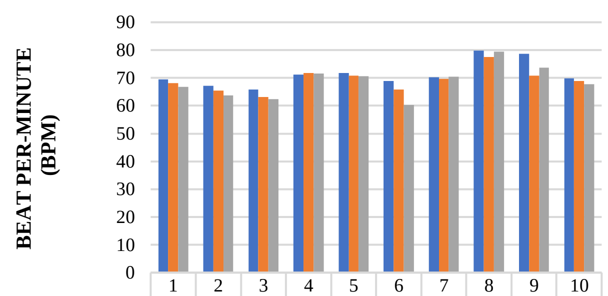
TABLE 2
Results Data of Heart Rate Measurements

RESPONDEN	Average Values of Heart Rate Measurements (BPM)			ERROR (%)	LOST DATA (%)
	COMPARISON DEVICE	MODUL BOX	ANDROID APLICATION		
1	69.4±5.7*bpm*	68.2±5.1*bpm*	66.8±5.7*bpm*	±1.73%	±2.05%
2	67.2±6.3*bpm*	65.4±6.5*bpm*	63.8±5.7*bpm*	±2.68%	±2.45%
3	65.8±5.6*bpm*	63.2±6.3*bpm*	62.4±6.8*bpm*	±3.95%	±1.27%
4	71.2±1.7*bpm*	71.8±3.8*bpm*	71.6±7.4*bpm*	±0.84%	±0.28%
5	71.8±6.6*bpm*	70.8±5.6*bpm*	70.6±6.9*bpm*	±1.39%	±0.28%
6	68.8±7.2*bpm*	65.8±10.7*bpm*	60.2±9.7*bpm*	±4.36%	±8.81%
7	70.2±6.4*bpm*	69.6±14.9*bpm*	70.4±15.9*bpm*	±0.85%	±1.15%
8	79.8±4.1*bpm*	77.6±4.8*bpm*	79.4±5.1*bpm*	±2.76%	±2.32%
9	78.6±6.8*bpm*	70.8±7.9*bpm*	73.6±8.7*bpm*	±9.92%	±3.95%
10	*69.8±9.9bpm*	68.8±7.4**bpm**	67.8±10.4*bpm*	±1.43%	±1.45%
AVERAGE				±2.82%	±0.89%

TABLE 2 These measurements were taken from 10 respondents, with 5 measurements conducted for each respondent. From the obtained data, the error between the device module and the reference device was calculated to

determine if the measurement results from the device module are in accordance with the reference device. The overall error calculation between the module and the reference device yielded a value of ± 2.82%, indicating that the heart rate readings from the device module are quite accurate when compared to the reference device, which is a pulse oximetry.

Additionally, the calculation was performed to determine the lost data between the data on the device module and the data sent to the Android application through Wi-Fi connection. The calculation for the lost data value between the device module and the data displayed on the Android application resulted in a value of ± 0.89%, indicating that the transmission of heart rate measurement data from the device module to the application is quite reliable. It is worth noting that the occurrence of lost data can be attributed to the fact that the module displays real-time data from the sensor, while the data sent and displayed on the application only represents the first 60 seconds of the measurement. Therefore, it is crucial to carefully and accurately retrieve data within the first 60 seconds to ensure accurate results.



	1	2	3	4	5	6	7	8	9	10
COMPARISON	69.4	67.2	65.8	71.2	71.8	68.8	70.2	79.8	78.6	69.8
MODUL	68.2	65.4	63.2	71.8	70.8	65.8	69.6	77.6	70.8	68.8
APPLICATION	66.8	63.8	62.4	71.6	70.6	60.2	70.4	79.4	73.6	67.8

FIGURE 8. **Average Values of Heart Rate Measurements on Comparison Device, Module Box, and Android Application**

In FIGURE 8. it shows a graph and the average values of heart rate measurements from 10 respondents on the device module, the comparison device, and the data displayed on the application. From the average data, differences in the measurement results can be observed between the module, the comparison device, and the data transmitted to the application.

IV. DISCUSSION

The measurement results of SpO_2 (blood oxygen saturation) and heart rate obtained using a MAX30102 sensor module. The SpO_2 measurements on 10 respondents, with 5 measurements each, yielded an average result of 96.48%. A comparison with a reference device showed an average error value of ±0.88%. This error could be attributed to excessive movements during measurement, which can affect the readings. The changes in absorbance components caused by movements can lead to lower saturation readings. Regarding data transmission, the comparison between the module's average SpO_2 data (96.48%) and the data received by the application (95.84%) indicated lost data during transmission, averaging ±0.66%. In terms of heart rate measurements, the average data obtained on the module was 69.2 bpm, while the comparison device recorded an average of 71.26 bpm, resulting in an average error value of ±2.82%. The module's design, similar to the comparison device, allows for optimal heart rate reading for 60 seconds by keeping the finger in place. However, excessive movements during measurement can affect the readings, leading to incomplete measurements. Regarding data transmission, a comparison between the module's average heart rate data (69.22 bpm) and the data received by the application (68.66 bpm) showed lost data during transmission, averaging ±0.89%.

When comparing the results of this study to the research conducted by I Putu Anna Andika about the portable pulse oximetry, which also utilized the same MAX30102 sensor, some differences can be observed. In Andika's study, the obtained error values were less than ±1%, which is within an acceptable range and indicates good sensor readings [14]. However, in the present study, the error values for heart rate exceeded ±1%, indicating less accurate readings. However, in to the research conducted by Raksha T Murthy, who created a design and development of IoT based pulse oximetry, which using the MAX30102 sensor, the research found a heart rate measurement error of 3.906%, indicating that the use of the MAX30102 sensor for heart rate measurement often experiences a relatively high error compared to SpO_2 measurement [8]. This discrepancy may be attributed to factors such as finger movements by the respondents during the measurements. Since the heart rate data is captured within the first 60 seconds of measurement, any movement during this period can affect the readings and lead to differences compared to the reference device or calibrator. Meanwhile, for lost data value if compared to the research conducted by Y. Y. Richa Rachmawati about web based temperature of oxygen saturation monitoring system, that utilizes Wi-Fi transmission displayed on a website, the result of that research was less than ±1% [4], and in this study, the obtained lost data result is also less than ±1% which can be concluded that the transmission process on this device is already good.

This also could be due to an unstable Wi-Fi network used for data transmission. However, despite the errors and lost data, the SpO_2 measurements remained within acceptable limits, as they did not fall below ±1%. Therefore, it can be concluded that the MAX30102 sensor is capable of measuring SpO_2 values well, and the ESP32 can adequately transmit data to the application. This loss of data could be attributed to imprecise timing during data capture and an unstable Wi-Fi network. And for the error value in heart rate measurements exceeded the acceptable limit of ±1%. To address this, educating respondents on the importance of keeping the finger steady for the full 60 seconds without movement can help improve accuracy. This ensures that the sensor accurately captures the heart rate per minute for the complete duration, resulting in better results. Addressing these weaknesses and limitations in future studies would strengthen the validity and reliability of the findings, providing a more robust understanding of the capabilities and limitations of the MAX30102 sensor module for measuring SpO_2 and heart rate.

The implications and benefits of the study's findings for society is to improved monitoring of vital signs, the study contributes to the development and understanding of the MAX30102 sensor module's capabilities in measuring SpO_2 and heart rate. This technology has the potential to enhance the accuracy and convenience of vital sign monitoring, providing valuable information for healthcare professionals and individuals monitoring their health at home. The use of sensor modules like MAX30102 has the potential to reduce healthcare costs by enabling efficient and accurate monitoring of vital signs. By minimizing the need for frequent hospital visits or in-person consultations, individuals and healthcare systems can save time and resources while still ensuring effective healthcare management. This knowledge can guide further research and development in sensor technology, leading to more advanced and accurate devices for vital sign monitoring in the future.

V. CONCLUSION

In conclusion, the study demonstrates that the MAX30102 sensor module has the capability to measure SpO_2 and heart rate with reasonable accuracy. The average SpO_2 results obtained were within an acceptable range, although there was a slight error when compared to the reference device. Similarly, the module provided fairly accurate heart rate measurements, although there was a slightly higher error rate. In the Kodular program, there is a feature to input personal data. The measurement data from the sensor can be stored and saved in the MySQL database. The data file can also be downloaded in the form of an Excel file (xlxs).

The average error value for oxygen saturation (SpO_2) measurements is approximately ±0.88%, while for heart rate per minute (BPM) measurements, the average error value is approximately ±2.82%. The average lost data value for oxygen saturation (SpO_2) measurements is approximately ±0.66%, and for heart rate per minute (BPM) measurements, the average lost data value is approximately ±0.89%. These conclusions indicate that the developed system provides relatively accurate measurements of SpO_2 and BPM values. However, there is a margin of error and a small amount of data loss during the measurement process. It is important to consider these factors when interpreting the results and ensuring proper measurement techniques to minimize errors and data loss.

Future work in this field should focus on addressing the limitations of the study and expanding the understanding of the MAX30102 sensor module's capabilities. This can be adding a graphical or signal display, enhancing the device by incorporating a visual representation, such as a graph or signal display, can provide a more intuitive understanding of the measured data. Improving the device's design, for the future work it can enhancing the overall design of the device to make it more ergonomic, user-friendly, and aesthetically pleasing. Optimizing for minimal interference, ensuring that the device is as ideal as possible and not affected by finger movements or external factors can improve the accuracy and reliability of the measurements. Exploring alternative sensors, for the future work it can consider exploring other sensors that are more practical and less dependent on finger movements. This could involve researching and testing different sensor options to find the most suitable alternative. By addressing these identified shortcomings, the author can improve the functionality, usability, and accuracy of the device in future iterations.

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