Elderly Health Monitoring System based on IoT

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ABSTRACT

The development of Internet of Things (IoT) technology has opened up great opportunities in improving the quality of health services, especially for the elderly who have a high risk of heart and respiratory disorders. This research aims to design and build an IoT-based elderly health monitoring system that is able to monitor three vital body parameters, namely heart rate and oxygen saturation (SpO_2) in real-time, and provide early warnings if abnormal conditions occur. This system uses MAX30102 sensors to measure heart rate and oxygen saturation. The NodeMCU ESP32 microcontroller is used as a data processing center connected to an I2C LCD for local display, buzzer as an alarm, and Blynk and Google Sheets applications for remote monitoring and data logging. The test results show that the system has a high accuracy rate, with an average accuracy of 98.88% for heart rate, 98.74% for oxygen saturation. The system is proven to work optimally and well integrated, making it feasible to be used as an independent and efficient elderly health monitoring tool.

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1. INTRODUCTION

The development of Internet of Things (IoT) technology has driven significant innovations in various sectors, including in healthcare. One of the main challenges in modern healthcare is the need for a real-time and continuous patient condition monitoring system, especially in the elderly who are prone to decreased organ function due to the aging process. The elderly often face a higher risk of coronary heart disease because aging causes the heart and blood vessels to stiffen. The death rate caused by coronary heart disease in Indonesia reaches 1.25 million people if the Indonesian population is 250 million people [1]. Where health services are one of the things that must be considered for the elderly population because they are vulnerable to disease [2]. This condition emphasizes the importance of a preventive health monitoring system that can detect early symptoms of health problems quickly. An Elderly Health Monitoring System is a system designed to observe, record, and analyze the health conditions of older adults in real time using sensors, electronic devices, and communication technology.

The heart as a human vital sign is very influential in daily life, where the heartbeat can ensure a person's health. The next vital sign that needs to be checked is oxygen saturation because it is important and affects the function of organs and tissues in the body [3]. Abnormal changes in these parameters can be early indicators of serious conditions such as arrhythmia, infection, or heart attack. Checking the condition of the heart is usually done with an electrocardiograph, but the use of medical devices is very expensive and inflexible to be used independently by patients [4]. Rising life expectancy has led to a continued rise in the number of elderly people worldwide, including in Indonesia. This situation demands special attention to the health of the elderly, as they are vulnerable to chronic diseases such as hypertension, diabetes, and heart disease. However, limited medical personnel and the distance between the elderly and their families often hinder routine health monitoring.

IoT-based system so that distance is not an obstacle in the monitoring process [5]. The utilization of IoT technology in health monitoring systems is an effective solution because it enables automatic data measurement and online data transmission via Wi-Fi networks. This technology allows families or medical personnel to monitor the patient's condition remotely, as well as provide early notifications when vital parameter values are detected outside normal limits.

This research aims to design and build an IoT-based elderly health monitoring system capable of measuring heart rate and oxygen saturation in real-time. This system uses MAX30102 sensor which is controlled by NodeMCU ESP32 microcontroller. The measurement results are displayed through the I2C LCD locally and sent to the Blynk application and Google Sheets for remote monitoring and recording. The system is also equipped with a buzzer as an early warning alarm. Based on the test results, the system shows a high level of accuracy and can function properly in an integrated manner, so that it can be used as an alternative independent health monitoring tool for the elderly.

2. METHOD

This research uses a systems engineering approach to design and build an Internet of Things (IoT)-based elderly health monitoring tool. The system is designed to monitor two vital body parameters: heart rate (BPM) and blood oxygen saturation (SpO_2), and provide early warning locally and remotely if abnormal values are found. The normal human heart rate ranges from 60-100 beats per minute [6]. A normal heart rate helps in transporting oxygen throughout the body. Normal blood oxygen saturation also helps the heart's performance so that we do not get tired easily [7]. The normal measure of oxygen saturation in the human body is 95-100% [8].

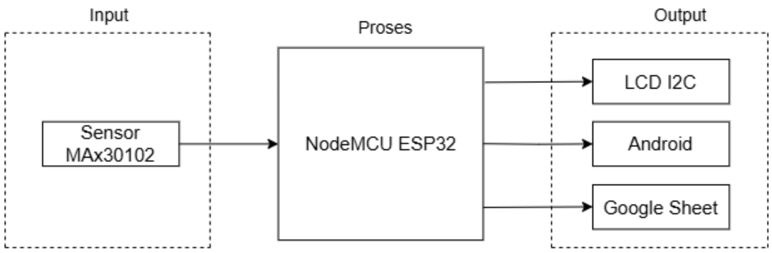


Figure 1. Block diagram

The main hardware used in this system consists of: MAX30102 sensor, to measure heart rate and SpO_2 using the photoplethysmography (PPG) method. The sensor uses infrared LED technology and a photodiode for the reflectivity method, emitting light absorbed by hemoglobin in the blood vessels of the skin to detect changes in blood volume [9]. NodeMCU ESP32 microcontroller, as the main controlling unit and data sender. ESP32 specifications are very complete, so this microcontroller is very appropriate to use, especially for applications that use or relate to the Internet of Things, because NodeMCU ESP32 has extensive communication capabilities, including the ability to connect via Wifi, Bluetooth Low Energy (BLE), and Bluetooth networks [10]. NodeMCU ESP32 is a microcontroller based on the ESP32 chip developed by Espressif Systems. ESP32 is an advanced version of the ESP8266 with higher capabilities, because it is equipped with: Dual-core processor (Xtensa LX6, up to 240 MHz), Wi-Fi and Bluetooth (BLE & Classic), more GPIO (General Purpose Input Output), ADC, DAC, PWM, I2C, SPI, UART features, and many more. NodeMCU ESP32 is widely used in Internet of Things (IoT) projects because it can connect directly to the internet network via Wi-Fi and also supports connections to sensors and other devices via digital communication protocols. The LCD monitor is used to display the data that has been sent by the sensor [11].

The software was developed through the Arduino IDE. Arduino IDE is software used to insert programs that contain commands and uploaded to the microcontroller for its application [12]. The work system of the internet of things (IoT)-based heart rate detector can be seen in the flowchart shown in Figure 2. Flowchart or often called a flowchart is a type of diagram that represents algorithms or sequential steps of instructions in the system [13].

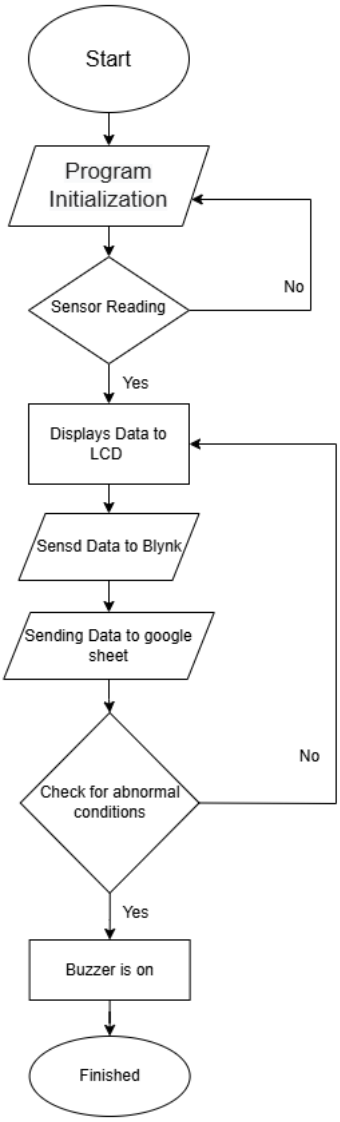


Figure 2. Flowchart

Hardware is a physically visible component that works together in data processing [14]. Through careful design can optimize and reduce the error rate when making hardware so as to achieve optimal results. The schematic circuit can be seen in Figure 3.

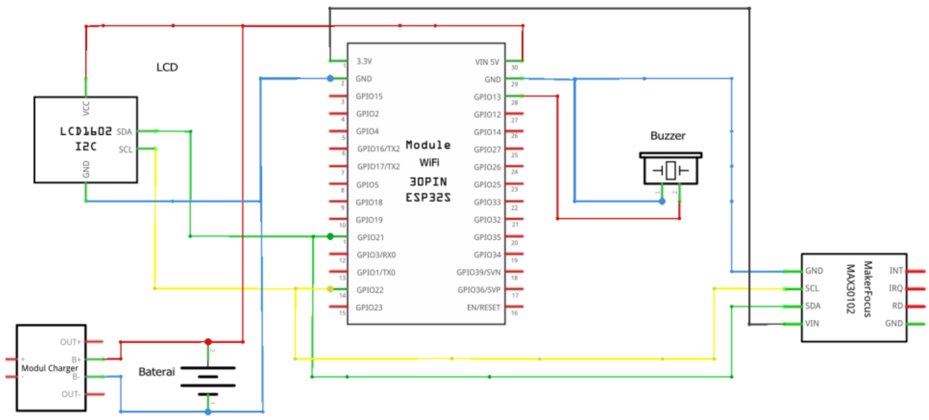
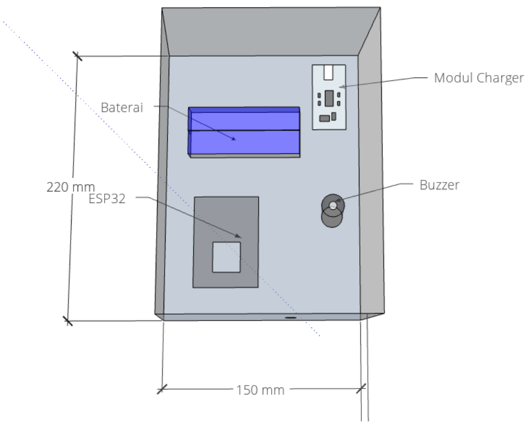
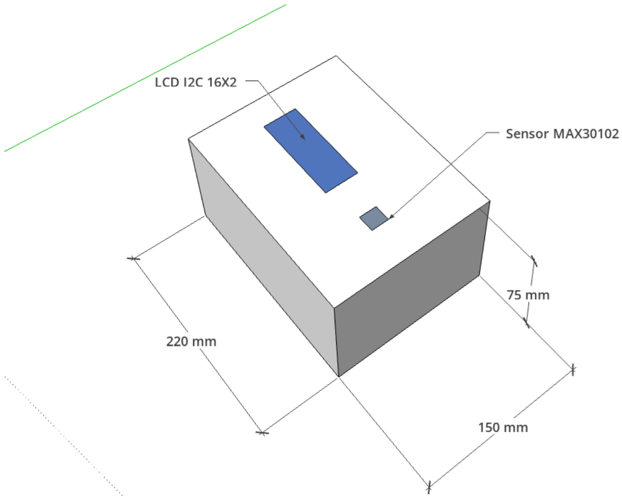


Figure 3. Schematic circuit

Mechanical design aims to provide an overview of the physical form of the mechanical which is useful as the placement of the position of the component or part so that it can function as desired when the program is run [15]. This mechanical design is made in 3D using the Skechup website and this can also help facilitate the assembly process, can be seen in Figure 4.



(a)



(b)

Figure 4. Physical Tool Design (a) Inside (b) Overall View

In the figure above, a three-dimensional (3D) physical design of the designed monitoring device is shown. This design is made so that the tool has an ergonomic shape, is portable, and is easy to use by the elderly. The explanation of the components is as follows: Casing Box is made of lightweight plastic material or printed using 3D printing. Serves as a protector of the entire electronic circuit to be safe from physical damage and easy to carry. The MAX30102 sensor is placed on the outside or side of the case and is designed so that the user's fingertips can touch the sensor easily. The 16x2 I2C LCD is placed on the top of the case to make it easier for users to read data directly without the need to open an application.

3. RESULTS AND DISCUSSION

Testing is an important stage in the system design process, which aims to ensure that all components, both hardware and software, have worked optimally and in accordance with the expected functions. In this final project, testing is carried out in stages, starting from testing each hardware component individually such as the MAX30102 sensor, I2C LCD, and buzzer, to the integration of the entire system as a whole. In addition to testing the physical components, software testing is also carried out which includes a microcontroller program to read data from sensors, display data to the LCD screen, send data to the Blynk platform as an Internet of Things (IoT) interface, and send data to Google Sheets via Web API for automatic recording. The overall shape of the device can be seen in Figure 5.

Figure 5. Overall shape of the tool

The accuracy value is a level of closeness between the predicted value and the actual value. The accuracy value is used to determine how close the measurement or prediction result is to the actual value. It is an important metric in evaluating the performance of a model or system, especially in the context of classification or prediction. The higher the accuracy value, the better the performance of the model or system.

$$\frac{pengukuran\ alat\ standar - pengukuran\ sensor}{pengukuran\ alat\ standar}\ x100\% \quad (1)$$

The total number of samples used for testing is 20 respondents with an age range ≥ 60 years or lasia, the data can be seen in the table. All data obtained can be used for testing the accuracy of the tool. Conducted when the respondent is resting or not doing activities. The following test data is presented in Table 1.

Table 1.Heart rate test results

NO.	AGE (YEARS)	OXIMETER (BPM)	MAX30102 SENSOR (BPM)	ACCURACY (%)
1.	60	98	100	97,96
2.	62	93	93	100
3.	60	106	107	99,06
4.	64	100	100	100
5.	66	98	97	98,98
6.	65	94	93	98,94
7.	61	83	83	100
8.	63	84	83	98,93
9.	60	102	100	98,04
10.	70	91	88	96,71
11.	69	94	93	98,94
12.	60	100	100	100
13.	60	91	90	98,91
14.	60	101	100	99,01
15.	62	108	104	96,3
16.	61	102	100	98,04
17.	63	90	90	100
18.	66	94	93	98,94
19.	60	84	83	98,81
20.	60	83	83	100
Average Accuracy				98,88

Table 1 is the data from testing the accuracy of heart rate (BPM) using the MAX30102 sensor, the results are not much different from the measurement of heart rate (BPM) using an oximeter. Where the average accuracy rate is 98.88%. So it can be concluded that the MAX30102 sensor in this study functions properly and can be used.

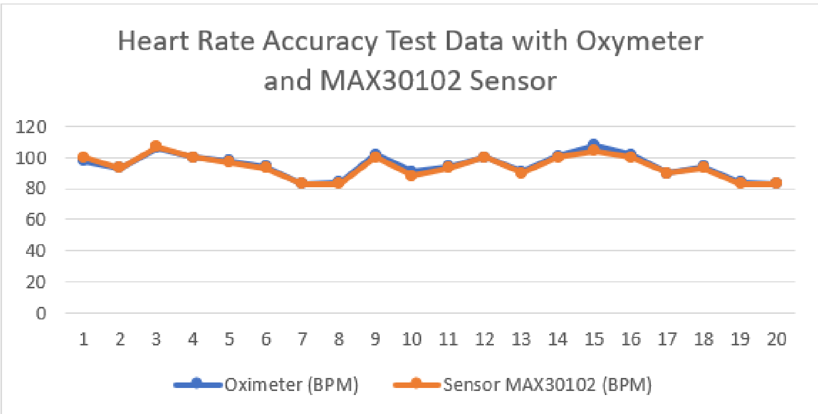


Figure 5. Graph of Max30102 sensor test results

The graph above shows the comparison of heart rate readings between the MAX30102 sensor and the Oximeter for 20 tests. Each pair of blue and orange lines represents the heart rate detected by both devices at the same time. Visually, it can be seen that the difference between the values measured by the MAX30102 sensor and the Oximeter is very small, even in most tests the results are identical.

Table 2. Oxygen Saturation Testing Results

No.	Age (Years)	Oximeter (%)	Max3012 Sensor (%)	Accuracy (%)
1	60	100	100	100
2	62	99	99	100
3	60	100	98	98
4	64	100	98	98
5	66	100	100	100
6	65	100	100	100
7	61	99	97	97,98
8	63	97	96	98,87
9	60	97	97	100
10.	70	102	100	98,04
11.	69	100	100	100
12.	60	100	99	99
13.	60	98	97	98,98
14.	60	99	98	98,99
15.	62	102	100	98,04
16.	61	100	97	97
17.	63	99	98	97,98
18.	66	99	96	96,97
19.	60	99	97	97,98
20	60	98	97	98,98
		Average Accuracy		98,74

Table 2 is the data from testing the accuracy of oxygen saturation (%) using the MAX30102 sensor, the results are not much different from measuring oxygen saturation using an oximeter. Where the average accuracy level is 98.78%. So it can be concluded that the MAX30102 sensor in this study functions properly and can be used.

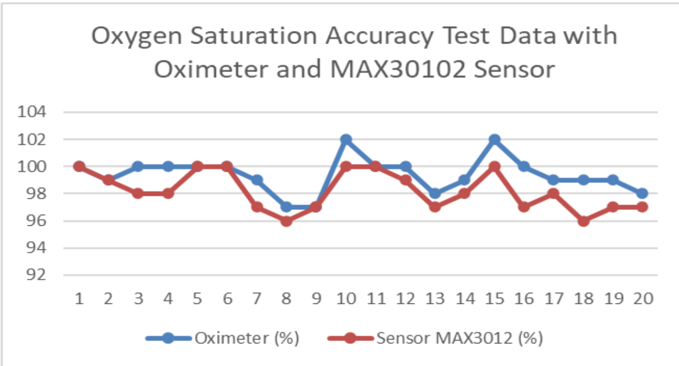


Figure 6. Graph of Max30102 sensor test results

The graph above shows the comparison of oxygen saturation readings between the MAX30102 sensor and the Oximeter for 20 tests. Each pair of blue and orange lines represents the oxygen saturation detected by both devices at the same time. Visually, it can be seen that the difference between the values measured by the MAX30102 sensor and the Oximeter is not much different.

4. CONCLUSION

This research successfully designed and implemented an Internet of Things (IoT)-based elderly health monitoring system capable of monitoring two main vital parameters, namely heart rate (BPM) and blood oxygen saturation (SpO_2) in real-time. The system uses a MAX30102 sensor controlled by a NodeMCU ESP32 microcontroller and supported by an I2C LCD display as a local interface and a buzzer as an early warning alarm. The measurement data is transmitted to the Blynk application via Wi-Fi connection and automatically logged to Google Sheets for documentation and remote monitoring purposes. Test results show that the system has a high level of accuracy, with an average heart rate measurement accuracy of 98.88% and oxygen saturation of 98.74% compared to standard medical devices. The system is also able to respond automatically to abnormal conditions by activating a buzzer as a local warning. Based on these results, the system is considered effective and feasible to be used as a self-monitoring tool for the elderly, especially for those who live alone or far from health facilities, to improve early detection and response to potential health problems.

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