International Journal on Smart Material and Mechatronics
IJSMM Vol. 2 No. 2 2025 DOI. 10.20342/IJSMM.2.2.373

p-ISSN: 2356-5314
e-ISSN: 2460-075X

Design and Development of a Heart Rate and Blood Oxygen Saturation Monitoring System Using a Fuzzy System Based on the Internet of Things

Muhammad Novian Darmawan, Wisnu Djatmiko
Electronics Engineering Education, Faculty of Engineering
State University of Jakarta
muhammadnoviandarmawan@gmail.com, wisnu.dj@unj.ac.id

Abstract*—Existing heart rate and oxygen saturation monitoring devices currently have limitations such as high cost, lack of portability, and the absence of automatic notification features for users. This study aims to design, build, and test a heart rate and blood oxygen saturation monitoring system using a portable and affordable fuzzy system based on the Internet of Things. The development method used is the V-Model, which includes systematic verification and validation stages. The system was built using an ESP32 microcontroller as the main processing unit, an AD8232 sensor to measure the heart's electrical activity, a MAX30102 sensor to measure heart rate and blood oxygen saturation (SpO2), and an MLX90614 sensor to measure body temperature. Data from the three sensors is processed using Mamdani fuzzy logic, then transmitted wirelessly to the Ubidots platform for real-time monitoring via smartphone. Testing was conducted on subjects aged 20–25 years performing a running activity on a treadmill for 30 minutes. The results show that the system is able to read and display heart rate, blood oxygen saturation, and body temperature data in real time. The Mamdani fuzzy logic successfully classified the user's health condition based on the acquired sensor data. The system is concluded to be feasible for use as a portable, affordable monitoring tool capable of providing early warnings to users when abnormal health conditions are detected during exercise.

Keywords*—heart rate, oxygen saturation, body temperature, fuzzy system, Internet of Things

I. INTRODUCTION

Exercise is a planned and structured physical activity that plays an important role in maintaining the health and endurance of the heart, lungs, and blood circulation (Puspodari, 2021). During exercise, the body undergoes physiological changes such as an increase in heart rate, changes in blood oxygen saturation (SpO2), and changes in body temperature. Real-time monitoring of these physiological parameters is therefore required so that the body's condition during exercise can be continuously observed (Rahma, Alkhoir, Al, & Ridho, 2026). The heart acts as the main pump distributing blood throughout the body, while blood oxygen level is another important parameter used to identify a person's health condition (Ria Hariri, Lutfi Hakim, & Riska Fita Lestari, 2021). Body temperature also needs to be monitored, since increased intensity of physical activity can trigger conditions such as heat exhaustion and hyperthermia if the body's thermoregulation mechanism is unable to compensate for the increase in heat produced (Izha, Basuki, & Habibi, 2025).

A heart rate and blood oxygen monitoring device was previously studied by (Tatilu, Sompie, & Wuwung, 2022), who designed an IoT-based device using a MAX30100 sensor and the Blynk platform; however, the readings were displayed only in text form. Another study by (Isma et al., 2020) developed an ECG device using an AD8232 sensor with an error of 2.282% compared to a Philips ECG device and 1.83% compared to an oscilloscope, but the ECG waveform was displayed only on the oscilloscope, making the device non-portable. Based on these studies, most prior research has focused on only one physiological parameter, and few have integrated heart rate, oxygen saturation, and body temperature simultaneously within a single portable, IoT-based system.

This research aims to address these limitations by designing a monitoring system that integrates an AD8232 sensor to read the heart's electrical activity, a MAX30102 sensor to measure heart rate and oxygen saturation, and an MLX90614 sensor to measure body temperature. These three parameters are processed using Mamdani fuzzy logic so that the system can automatically classify the user's health condition; the data is then transmitted wirelessly to the Ubidots platform so it can be monitored in real time via smartphone. The purpose of this research is to design, build, and test the performance of a heart rate and blood oxygen saturation monitoring system prototype using a fuzzy system based on the Internet of Things, in order to determine the accuracy of each sensor, the performance of the data communication, and the level of agreement between the fuzzy classification results and a physician's assessment.

II. THEORETICAL BASIS

A. ESP32

The ESP32 is a microcontroller introduced by Espressif System as the successor to the ESP8266, equipped with an on-chip WiFi module that strongly supports Internet of Things applications. The ESP32 has a dual-core processor, supports Wi-Fi and Bluetooth, and provides GPIO pins, an 18-channel ADC, and a 2-pin DAC (Yusro et al., 2021). In this study, the ESP32 functions as the main processing unit, reading data from the MAX30102 and MLX90614 sensors via the I2C interface, processing the heart rate, SpO2, and body temperature values using Mamdani fuzzy logic, and then transmitting the entire dataset to the Ubidots platform via the WiFi network.

B. Arduino Nano and the ESP-01 WiFi Module

The Arduino Nano is a small microcontroller development board based on the ATmega328P chip, functionally equivalent to the Arduino Uno (Hakim, Budijanto, & Widjanarko, 2018). The ESP-01 is a low-cost WiFi module based on the ESP8266 chip that operates at 3.3 V and supports the IEEE 802.11 b/g/n wireless network standard (Yanti, Alfina, & Hidayat, 2024). In this study, the Arduino Nano is used to read and process the analog ECG signal from the AD8232 module at a sampling frequency of approximately 500 Hz; the resulting data is then sent to the ESP-01 module via UART communication so it can be forwarded to the Ubidots platform through the WiFi network.

C. AD8232 Module (ECG Sensor)

The AD8232 sensor module is a signal-conditioning block capable of extracting, filtering, and amplifying the heart's biopotential signal through electrodes placed on the body, based on Einthoven's triangle bipolar-lead theory (Hariri et al., 2021). This module uses a 3-lead ECG configuration with a yellow (positive), red (negative), and green (ground) electrode. In this study, the AD8232 sensor is used to read the user's electrocardiogram (ECG) signal, which is subsequently displayed as a visual graph of the heart's electrical activity on the Ubidots platform, without being used as an input to the fuzzy logic process.

D. MAX30102 Module (Heart Rate and SpO2 Sensor)

The MAX30102 is a sensor module produced by Maxim Integrated that can measure heart rate and blood oxygen saturation simultaneously using an infrared light emitter and a photodetector that detects changes in light intensity. This sensor has an I2C interface with a data rate of up to 400 kHz and a temperature accuracy of ±1°C (Muthmainnah, Deni Bako Tabriawan, & Imam Tazi, 2022). In this study, the MAX30102 sensor is placed on the user's finger and functions to read the heart rate (BPM) and blood oxygen saturation (SpO2) values in real time, which are then transmitted to the ESP32 for further processing.

E. MLX90614 Module (Body Temperature Sensor)

The MLX90614 sensor module, manufactured by Melexis, consists of an MLX81101 infrared detector and an MLX90302 signal-processing chip that can read an object's temperature without direct contact, with a resolution of up to 0.01°C (Ode et al., 2022). This sensor has a supply-voltage range of 3–5 V and a temperature accuracy of 0.5°C over a range of −40°C to 125°C. In this study, the MLX90614 sensor is used to measure the user's body temperature non-contactly at the finger, with the result sent to the ESP32 as one of the fuzzy system's input variables.

F. Li-Po Battery and the LM2596 Step-Down Module

A Li-Po (Lithium Polymer) battery is a portable power source with a high energy density commonly used in embedded systems, while the LM2596 step-down module functions to reduce a DC voltage to the level required by the electronic components. In this study, a 12 V Li-Po battery is used as the system's main power source, with the voltage stepped down through two LM2596 modules to 5 V and 3.3 V to supply the ESP32, ESP-01, Arduino Nano, and all sensors, allowing the entire system to be operated portably without a wired power supply.

G. Mamdani Fuzzy Logic

Fuzzy logic is a development of Boolean logic that introduces a partial degree of truth to handle uncertainty and ambiguity in decision-making (Nasution, 2020). The Mamdani method is a flexible approach with an intuitive advantage over purely statistical approaches (Maryam, Bu'ulolo, & Hatmi, 2021), and consists of four stages: fuzzification, implication, aggregation, and defuzzification. The membership function used in this study is a Gaussian curve, formulated as follows:

$$\mu(x) = \exp\left(-\left((x - c)^2\right) / \left(2\sigma^2\right) \right) \quad (1)$$

where $\mu(x)$ is the degree of membership of the input value x, c is the center of the curve, and σ is the standard deviation that determines the width of the curve (Rindengan & Yohanes, 2019). In this study, Mamdani fuzzy logic is used to classify the user's health condition into three categories—Poor, Caution, and Healthy—based on the heart rate, oxygen saturation, and body temperature values read by the sensors.

H. Ubidots

Ubidots is an Internet of Things (IoT) platform that simplifies the process of acquiring data from input devices and provides a dashboard and API for exchanging data between devices (Putra, Prof, & Air, 2021). In this study, Ubidots is used as a remote monitoring medium that displays the ECG signal graph, heart rate value, oxygen saturation, body temperature, and fuzzy classification results in real time via the MQTT protocol, so that the user's condition can be monitored via smartphone anytime and anywhere.

I. Related Research

Several relevant studies were used as references for the development of this system. (Hariri et al., 2021) designed a heart rate monitoring system using an AD8232 sensor with an ESP8266 and a 16x2 LCD display, but it was not equipped with an oxygen saturation or body temperature sensor.

p-ISSN: 2356-5314
e-ISSN: 2460-075X

(Ramlan Bugis, Nur'Aidha, & Kumarajati, 2024) developed a portable heart rate monitoring device using a MAX30102 sensor with an Arduino Uno and an OLED display, but it read only a single parameter. (Zidni & Ikrimach, 2023) applied fuzzy logic and ESP32-based IoT for heart-rate health classification via Firebase, but did not involve oxygen saturation or body temperature. (Muthmainnah et al., 2022) characterized the MAX30102 sensor to measure heart rate and body temperature based on photoplethysmography with an LCD display, while (Pratama, Bangsa, & Rahmadewi, 2020) implemented a MAX30100 heart-rate sensor and a GSR skin-conductance sensor on an Arduino microcontroller with the Blynk application to detect stress levels. Based on these studies, most prior work uses only a single type of sensor and has not yet combined heart rate, oxygen saturation, and body temperature readings with an integrated fuzzy classification process connected to IoT. This research develops a system that combines the AD8232, MAX30102, and MLX90614 sensors connected to the Ubidots platform, so that all three physiological parameters can be monitored and classified in real time within a single integrated system.

III. RESEARCH METHODOLOGY

A. Research Location and Time

This research was carried out at the Electronics Control Instrumentation Laboratory, Electronics Engineering Education Study Program, Faculty of Engineering, Universitas Negeri Jakarta, from May 2025 to June 2026.

B. Development Method

This research uses the Research and Development (R&D) method with the V-Model development approach, an enhancement of the waterfall method that emphasizes paired verification and validation stages at every development phase (Maulana & Subariah, 2022). This model was chosen because it can ensure that system verification and validation are carried out systematically across nine stages: Requirement Analysis, Specifications, Architectural Design, Detail Design, Coding, Unit Testing, Integration Testing, System Testing, and Acceptance Testing (Windi Eka, 2013).

At the Requirement Analysis and Specifications stage, the system requirements were identified for reading heart rate, oxygen saturation, and body temperature in real time and classifying the condition using IoT-based fuzzy logic. The Architectural Design and Detail Design stages produced the hardware and software architecture, while the Coding stage implemented the program on the ESP32, Arduino Nano, and ESP-01 microcontrollers using the Arduino IDE. Staged testing was then carried out through Unit Testing, Integration Testing, System Testing, and finally Acceptance Testing to ensure that all system functions operated according to user requirements.

C. System Design

The prototype developed consists of an ESP32 microcontroller as the main controller, an Arduino Nano and ESP-01 for processing and transmitting the ECG signal, an AD8232 sensor to read the heart's electrical activity, a MAX30102 sensor to measure heart rate and oxygen saturation, an MLX90614 sensor to measure body temperature, a Li-Po battery with an LM2596 step-down module as the power supply, and the Ubidots platform as the remote monitoring medium.

The system begins by initializing all devices, after which the ESP32 and ESP-01 check the WiFi connection. If the connection is successful, the MAX30102 sensor reads the SpO2 and heart rate values, while the MLX90614 sensor reads body temperature; both datasets are sent to the ESP32 for processing. In parallel, the AD8232 sensor reads the ECG signal, which is processed by the Arduino Nano before being forwarded to the ESP-01. The ESP32 and ESP-01 then send all the data to the Ubidots platform to be displayed as real-time monitoring graphs, including the ECG graph, heart rate value, SpO2, body temperature, and the fuzzy classification result.

D. Fuzzy Logic Variables and Rules

The fuzzy logic variables were determined based on three input parameters—heart rate, oxygen saturation, and body temperature—and one output variable representing the health-condition classification. The fuzzy logic variables used are shown in Table 3.1.

TABLE 3.1. FUZZY LOGIC VARIABLES

Variable	Fuzzy Set	Universe of Discourse	Domain	Description
Heart Rate	μ11	[0–200]	[0–50]	Low
	μ12		[50–150]	Normal
	μ13		[150–200]	High
Oxygen Saturation	μ21	[80–100]	[80–85]	Low
	μ22		[85–95]	Medium
	μ23		[95–100]	High
Body Temperature	μ31	[30–40]	[30–32.5]	Low
	μ32		[32.5–38]	Normal
	μ33		[38–40]	High
Fuzzy Output	μ41	[0–1]	[0–0.25]	Poor
	μ42		[0.25–0.75]	Caution
	μ43		[0.75–1]	Healthy

Based on these variables, 27 IF-THEN fuzzy rules were formulated using the Minimum implication function (Azmiana, Bu'ulolo, & Siagian, 2013), expressed as:

$$\text{IF } (x_1 \text{ is } A_1) \text{ AND } (x_2 \text{ is } A_2) \text{ AND ... AND } (x_n \text{ is } A_n) \text{ THEN } y \text{ is } B \quad (2)$$

All rules with a firing strength greater than zero are then combined during the aggregation stage using the Maximum operator, and the final result is defuzzified using the Mean of

Test	Measured Value (V)
Li-Po Battery	12.03 V
LM2596 (Output 1)	5.02 V
LM2596 (Output 2)	3.35 V

Maximum (MoM) method to obtain a crisp value for the user's health-condition classification.

E. Data Collection and Analysis Technique

Data collection was carried out through the testing stages of the V-Model, comprising Unit Testing, Integration Testing, System Testing, and Acceptance Testing. The tests included: (1) testing of the voltage source and the Li-Po battery's operating duration using a multimeter; (2) accuracy testing of the MAX30102 sensor for heart rate and oxygen saturation, compared against a pulse oximeter as the reference instrument; (3) accuracy testing of the MLX90614 sensor for body temperature, compared against a thermometer; (4) testing of the Ubidots platform as the monitoring medium; (5) testing of the Mamdani fuzzy logic through a Fuzzy Inference System simulation in MATLAB software; and (6) validation of the fuzzy classification results against a physician's assessment. Testing was conducted on five subjects aged 20–25 years under three activity conditions—before running, while running, and after running on a treadmill for 30 minutes. The measurement error value was calculated using Equation 3:

$$\text{Error} = \left| (\text{Reference value} - \text{sensor value}) / \text{Reference value} \times 100\% \right| \qquad (3)$$

IV. RESULTS AND DISCUSSION

A. Product Design Results

The heart rate and blood oxygen saturation monitoring system prototype was successfully realized according to the design using an ESP32 microcontroller as the main controller, with the overall appearance of the device shown in Figure 4.1.

Fig. 4.1. Overall Appearance of the Monitoring Device

The system consists of a 12 V Li-Po battery as the power source, an Arduino Nano for processing the ECG signal from the AD8232 module, an ESP32 for processing heart rate and oxygen saturation data from the MAX30102 and MLX90614 sensors, an ESP-01 for transmitting ECG data, a DC step-down module to lower the voltage, a DC jack, a battery indicator, and a switch to turn the device on and off. All components are packaged in a single portable casing so that the system can be carried and used directly during exercise.

B. Voltage Source and Li-Po Battery Testing Results

Voltage source testing was carried out using a multimeter to measure the input and output voltage of the step-down module. The results are shown in Table 4.1.

TABLE 4.1. VOLTAGE SOURCE TESTING RESULTS

The test results show a battery input voltage of 12.03 V and step-down module output voltages of 5.02 V and 3.35 V, indicating that the battery adequately supports the power requirements of all system hardware. Testing of the battery's operating duration showed that the battery voltage decreased gradually from 12.01 V at the start of testing to 11.44 V after five hours of continuous use, indicating that the Li-Po battery is able to supply the system's power stably over that duration.

C. MAX30102 Sensor Testing Results (Heart Rate and Oxygen Saturation)

Heart rate accuracy testing was carried out by comparing the sensor readings against a pulse oximeter under three activity conditions, with the results shown in Table 4.2.

TABLE 4.2. HEART RATE TEST RESULTS

Condition	Subject	Sensor (BPM)	Pulse Oximeter (BPM)	Error
Before Running	1	85	84	1.2%
	2	81	77	5.2%
	3	94	91	3.3%
	4	90	92	2.2%
	5	87	85	2.4%
While Running	1	130	126	3.2%
	2	134	137	2.2%
	3	140	143	2.1%
	4	136	138	1.4%
	5	142	140	1.4%
After Running	1	90	96	6.3%
	2	93	92	1.1%
	3	120	123	2.4%
	4	123	122	0.8%
	5	110	108	1.9%

The heart rate error ranged from 1.2%–5.2% before running, 1.4%–3.2% while running, and 0.8%–6.3% after running. These differences are likely influenced by sensor placement, subject movement, signal noise, and differences in reading time between the sensor and the reference instrument. The oxygen saturation (SpO2) test results are shown in Table 4.3.

TABLE 4.3. OXYGEN SATURATION TEST RESULTS

Condition	Subject	MAX30102 Sensor	Pulse Oximeter (SpO2)	Error
Before Running	1	98%	99%	1.0%
	2	100%	99%	1.0%
	3	99%	98%	1.0%

p-ISSN: 2356-5314
e-ISSN: 2460-075X

Condition	Subject	MAX30102 Sensor	Pulse Oximeter (SpO2)	Error
	4	98%	98%	0.0%
	5	96%	97%	1.0%
While Running	1	94%	98%	4.1%
	2	94%	97%	3.1%
	3	100%	98%	2.0%
	4	92%	95%	3.2%
	5	94%	95%	1.1%
After Running	1	98%	98%	0.0%
	2	94%	92%	2.2%
	3	98%	99%	1.0%
	4	96%	98%	2.0%
	5	96%	98%	2.0%

The oxygen saturation error ranged from 0%–1% before running, 0%–4.1% while running, and 0%–2.2% after running, indicating that the accuracy of the MAX30102 sensor is relatively good compared with the pulse oximeter reference instrument across all test conditions.

D. MLX90614 Sensor Testing Results (Body Temperature)

Body temperature accuracy testing was carried out by comparing the MLX90614 sensor readings against a thermometer, with the results shown in Table 4.4.

TABLE 4.4. BODY TEMPERATURE TEST RESULTS

Condition	Subject	MLX90614 Sensor	Thermometer	Error
Before Running	1	37.2°C	36.8°C	1.1%
	2	35.0°C	36.7°C	4.6%
	3	36.4°C	36.9°C	1.4%
	4	37.5°C	37.4°C	0.3%
	5	37.0°C	37.2°C	0.5%
While Running	1	36.5°C	36.6°C	0.3%
	2	36.5°C	36.6°C	0.3%
	3	36.8°C	36.9°C	0.3%
	4	37.8°C	37.8°C	0.0%
	5	37.5°C	37.3°C	0.5%
After Running	1	36.6°C	36.6°C	0.0%
	2	37.0°C	36.8°C	0.5%
	3	36.4°C	36.9°C	1.4%
	4	37.6°C	37.5°C	0.3%
	5	37.2°C	37.2°C	0.0%

The body temperature error ranged from 0.3%–4.6% before running, 0%–0.5% while running, and 0%–1.4% after running. Overall, the MLX90614 sensor produced readings close to the thermometer values, with possible sources of the discrepancy including the sensor's distance from the object, ambient conditions, and the sensor's position during measurement.

E. Ubidots Platform Testing Results

Testing of the Ubidots platform was carried out by connecting all sensors to the microcontroller, which was already connected to the WiFi network. The results are shown in Table 4.5.

TABLE 4.5. UBIDOTS PLATFORM TESTING RESULTS

Display	Successes	Failures	Success Rate
ECG Signal Graph	15	0	100%
Heart Rate Value (BPM)	15	0	100%
Oxygen Saturation Value	15	0	100%
Body Temperature	15	0	100%
Fuzzy Classification Result	15	0	100%

The test results show that the Ubidots platform is able to display the ECG graph, heart rate value, oxygen saturation, body temperature, and fuzzy classification results with a 100% success rate under the before-, during-, and after-running conditions.

F. Mamdani Fuzzy Logic Testing Results

Testing of the Mamdani fuzzy logic was carried out through a simulation in MATLAB software using a case study of a 130 BPM heart rate, 90% oxygen saturation, and a body temperature of 36.8°C. At the fuzzification stage, using the Gaussian equation, the membership degrees obtained were: heart rate $\mu 12$ (Normal) = 0.3247, oxygen saturation $\mu 22$ (Medium) = 1.0000, and body temperature $\mu 32$ (Normal) = 0.8148. At the implication stage, using the Minimum operator, one of the active rules—Rule 14 (Heart Rate Normal AND Oxygen Saturation Medium AND Body Temperature Normal THEN Caution)—produced a firing strength of 0.3247. At the aggregation stage, using the Maximum operator, the membership degrees obtained were 0.0378 for Poor, 0.3247 for Caution, and 0.00387 for Healthy, so the maximum value fell in the Caution category. The defuzzification process, using the Mean of Maximum (MoM) method, produced a crisp value of 0.5, indicating that the health condition in this case study was classified as Caution.

The resulting surface-plot visualization of the fuzzy inference system shows that oxygen saturation is the most dominant variable affecting the output value, as seen from the sharp change in output when oxygen saturation drops into the 80–85% range, while heart rate is dominant at extreme values (near 0 or 200 BPM). Body temperature has a relatively smaller influence than the other two variables, acting more as a supporting factor in the health-condition classification process.

G. Validation of Fuzzy Output Against a Physician's Assessment

Validation was carried out by comparing the fuzzy system's classification results against a physician's assessment for 15 test data points (5 subjects × 3 activity

p-ISSN: 2356-5314
e-ISSN: 2460-075X

conditions). A summary of the validation results is shown in Table 4.6.

TABLE 4.6. FUZZY CLASSIFICATION TEST RESULTS COMPARED TO PHYSICIAN ASSESSMENT

Condition	Data Points	Matched	Not Matched	Agreement Rate
Before Running	5	4	1	80%
While Running	5	5	0	100%
After Running	5	5	0	100%
Total	15	14	1	93.33%

Based on Table 4.6, out of 15 test data points, 14 matched the physician's assessment and 1 did not, giving an agreement rate of 93.33% with an error of 6.67%. The mismatch occurred in the before-running condition, where the system classified the subject as Caution while the physician assessed the subject as still Healthy. This difference was caused by the subject's body temperature being at the upper boundary of the normal category, so the fuzzy inference rules directed the classification result toward the Caution status as a form of early caution, rather than due to an error in the system's logic.

V. ANALYSIS

Based on the overall test results, the heart rate and blood oxygen saturation monitoring system prototype using a fuzzy system based on the Internet of Things has met the research objectives as a system capable of reading heart rate, oxygen saturation, and body temperature in real time, classifying the user's health condition, and displaying all data through the Ubidots platform. The MAX30102 and MLX90614 sensors showed good accuracy with relatively small error values, while data communication to the Ubidots platform was successfully achieved with a 100% success rate. The Mamdani fuzzy logic successfully classified the user's health condition with a 93.33% agreement rate compared to the physician's assessment, indicating that the system is sufficiently reliable for use as a tool to assist in real-time monitoring of an athlete's health condition. The main limitation of the system lies in the single classification mismatch that occurred at the boundary condition of normal body temperature, as well as the possible influence of body movement, sensor placement, and internet connection stability on reading accuracy, so further refinement is still required.

VI. CONCLUSION AND SUGGESTIONS

A. Conclusion

Based on the design, construction, and testing results, it can be concluded that a heart rate, oxygen saturation, and body temperature monitoring system based on the Internet of Things using the Mamdani fuzzy method was successfully developed through the V-Model approach. The system is able to measure heart rate and oxygen saturation using the MAX30102 sensor, measure body temperature using the MLX90614 sensor, read the ECG signal using the AD8232 sensor, and classify the user's health condition into three categories—Poor, Caution, and Healthy—in real time via the Ubidots platform.

The test results show a heart rate error ranging from 0.8%–6.3%, an oxygen saturation error of 0%–4.1%, and a body temperature error of 0%–4.6% compared with standard reference instruments. All data was successfully displayed on the Ubidots platform with a 100% success rate. The fuzzy classification results showed a 93.33% agreement rate with the physician's assessment. The developed system is therefore considered feasible for use as a portable, affordable health monitoring tool capable of providing early warnings to users during exercise.

B. Suggestions

Future development is recommended to use an alternative IoT platform besides Ubidots, given the data storage capacity limitations of the free version. In addition, the device's dimensions need to be made more compact with smaller components for more comfortable daily use, and optimization of battery power consumption is required without reducing the system's operating duration.

ACKNOWLEDGMENT

The authors would like to thank Allah SWT and all parties who provided support, assistance, and contributions to the implementation and completion of this research. Thanks are also extended to everyone who helped with the prototype.

REFERENCES

[1] Azmiana, Z., Bu'ulolo, F., & Siagian, P. (2013). Penggunaan Sistem Inferensi Fuzzy Untuk Penentuan Jurusan Di Sma Negeri 1 Bireuen. Saintia Matematika, 1(3), 233–247.

[2] Hakim, D. P. A. R., Budijanto, A., & Widjanarko, B. (2018). Jurnal iptek. JURNAL IPTEK MEDIA KOMUNIKASI TEKNOLOGI, 22, 9–18. https://doi.org/10.31284/j.iptek.2018.v22i2

[3] Izha, H. M., Basuki, B. M., & Habibi, A. (2025). Desain dan Implementasi Rompi Pintar berbasis IoT untuk Monitoring Suhu Tubuh dan Detak Jantung saat Olahraga secara Real time, 19(1), 111–118.

[4] Maryam, S., Bu'ulolo, E., & Hatmi, E. (2021). Penerapan metode fuzzy mamdani dan fuzzy tsukamoto dalam menentukan harga mobil bekas. Journal of Informatics, Electrical and Electronics Engineering, 1(1), 10–14.

[5] Maulana, D., & Subariah, R. (2022). Perancangan Aplikasi Manajemen Informasi Dengan Model-V Berbasis Web Pada Himpunan Mahasiswa Sistem Informasi Universitas Pamulang. OKTAL: Jurnal Ilmu Komputer Dan Science, 1(11), 1963–1978.

[6] Muthmainnah, M., Deni Bako Tabriawan, & Imam Tazi. (2022). Karakterisasi Sensor MAX30102 Sebagai Alat Ukur Detak Jantung dan Suhu Tubuh Berbasis Photoplethysmograph. Jurnal Pendidikan Mipa, 12(3), 726–731. https://doi.org/10.37630/jpm.v12i3.655

[7] Nasution, H. (2020). Implementasi Logika Fuzzy pada Sistem Kecerdasan Buatan. ELKHA: Jurnal Teknik Elektro, 4(2), 4–8.

[8] Ode, W., Nur, S., Aliansyah, A. N., Larobu, F. E., Dinianti, N. Z., Mulyawati, L., & Galugu, I. (2022). Tingkat akurasi Sensor AMG8833 dan Sensor MLX90614 dalam Mengukur Suhu Tubuh. JTEV (Jurnal Teknik Elektro Dan Vokasional), 8(1), 169–179.

[9] Pratama, R. A., Bangsa, I. A., & Rahmadewi, R. (2020). Implementasi Sensor Detak Jantung MAX30100 dan Sensor Konduktansi Kulit GSR menggunakan Mikrokontroller Arduino Pada Alat Pendeteksi Tingkat Stress. Jurnal Ilmiah Wahana Pendidikan, 6(3), 295–307. https://doi.org/10.5281/zenodo.4541288

[10] Puspodari. (2021). Tingkat Volume Oksigen Maksimal Atlet Cabor Konsentrasi Unggulan Senam Puslatkot Kota Kediri Dalam Menghadapi Pekan Olahraga Provinsi 2022. Jurnal Kejaora (Kesehatan Jasmani Dan Olah Raga), 6(1), 207–211. https://doi.org/10.36526/kejaora.v6i1.1296

[11] Putra, A. T., Prof, J., & Air, H. (2021). Penggunaan Aplikasi Ubidots untuk Sistem Kontrol dan Monitoring pada Gudang Gula Berbasis Arduino UNO, 2(1), 40–48.

[12] Rahma, Q., Alkhoir, M., Al, F., & Ridho, F. (2026). Pemantauan Detak Jantung Berbasis Sensor MAX30102. Jurnal Otomasi, Kendali Dan Aplikasi Industri, 08(01), 1–6. https://doi.org/10.21009/autocracy.081.03

[13] Ramlan Bugis, E. R., Nur'Aidha, A. C., & Kumarajati, D. Y. H. (2024). Alat Monitoring Detak Jantung Portable Menggunakan Sensor Max30102. Jurnal Informatika Dan Teknik Elektro Terapan, 12(3). https://doi.org/10.23960/jitet.v12i3.4504

[14] Ria Hariri, R. H., Lutfi Hakim, L. H., & Riska Fita Lestari, R. F. L. (2021). Sistem Monitoring Detak Jantung Menggunakan Sensor AD8232. Journal Zetroem, 2(2), 1–5. https://doi.org/10.36526/ztr.v2i2.1017

[15] Rindengan, A., & Yohanes, A. L. (2019). Sistem Fuzzy. Sistem Fuzzy.

[16] Tatilu, A. E., Sompie, S., & Wuwung, J. O. (2022). Jurnal Agisty_saturasi oksigen, 1–14.

[17] Windi Eka. (2013). Perbandingan V-Model Tradisonal Dan Advanced V-Model. Prosiding Seminar Ilmu Komputer (SeNAIK 2013), 49.

[18] Yanti, Y., Alfina, A., & Hidayat, T. (2024). Sistem Monitoring Keamanan Kantor Berbasis Android Menggunakan Modul Wireless ESP-01. JITET (Jurnal Informatika Dan Teknik Elektro Terapan), 12(1).

[19] Yusro, M., Diamah, A., Sakti, I., Regowo, B., Zuhdi, I., & Izuddin, A. (2021). Modul Pembelajaran Teori & Praktek Aplikasi IoT. Sustainability (Switzerland).

[20] Zidni, G. S., & Ikrimach, I. (2023). Implementasi Metode Fuzzy Logic dan IoT untuk Klasifikasi Kondisi Kesehatan Denyut Jantung berbasis Android. Edumatic: Jurnal Pendidikan Informatika, 7(2), 366–375. https://doi.org/10.29408/edumatic.v7i2.23092