Prayer Guide Strap for the Deaf and Blind Using Gyroscope Sensors Based on Wireless Sensor Network

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***Abstract* – Indonesia is a country with a majority Muslim population of 237.558 million people or 86.7%, and 5% or 16.5 million of them are people with disabilities. In performing congregational prayers, deaf and blind people have difficulty following the imam's movements, sometimes having to look left and right when changing prayer movements. This can reduce the solemnity of prayer. This study aims to help deaf people pray in congregation and follow the imam's movements. The method used is by utilizing a gyroscope sensor that can read changes in the Y axis which will later be processed by Arduino Uno so that it can distinguish various imam movements and will later be sent in the form of vibration notifications to the prayer follower with disabilities. The communication used is wireless using the LoRa SX1278 RA-02 module. This study shows that by using the LoRa SX1278 RA-02 module, the signal emitted by the imam can be received by the prayer follower in all corners of the 336 meter mosque. This tool can detect prayer movements in 3 different numbers of rakaats, namely 2, 3, and 4 rakaats, with a success rate of this strap reaching 100%.**

Keyword: Disabilities, Deaf, Gyroscope, LoRa, Prayers

I. INTRODUCTION

Indonesia is the country with the largest Muslim population in the world according to a report from The Royal Islamic Strategic Studies Centre (RISSC). Of Indonesia's total population of approximately 274 million, 237.558 million people are Muslim, or 86.7% of the population [1]. 16.5 million people, or about 5% of the population, are persons with disabilities. According to the World Health Organization (WHO), disability is the inability to perform certain activities or tasks like a normal person, caused by psychological or physiological conditions or abnormalities in anatomical structure or function. Law No. 8 of 2016 further explains that persons with disabilities are individuals who experience long-term physical, intellectual, mental, and/or sensory limitations that, when interacting with their environment, may encounter barriers and difficulties in participating fully and effectively with other citizens based on equal rights. According to a disability study conducted by the Ministry of National Development Planning/BAPPENAS [2], 63.7% of people with visual impairments (people with visual disabilities) are the most common type of disability in Indonesia. Meanwhile, 29% of the total number of people with disabilities in Indonesia are deaf (hearing impaired), and 48.7% have multiple disabilities.

Deafness is a condition in which a person has a hearing impairment, meaning they cannot hear some or all sounds in one or both ears [3]. This condition causes people with deafness to experience difficulties in their daily activities because they have to use sign language, including when performing the prayer. As Muslims, people with deafness also have an obligation to perform the five daily prayers. However, when deaf people perform congregational prayers, they must look left and right to see the movements of the imam. This is especially difficult during prostration, when it is hard to tell whether the imam has risen from prostration or not, often causing the deaf prayer follower to precede the imam. This makes them anxious, reducing their concentration during prayer.

Hearing aids that are widely available in the community cannot be used by all deaf people, especially those with severe deafness [4]. Hearing aids can also interfere with concentration during prayer because they often produce a buzzing sound. The same thing is experienced by people with multiple disabilities, such as deaf and blind people. They face even more difficulties because, in addition to hearing impairments, they also have visual impairments that are used to help them perform congregational prayers. Therefore, a tool is needed to help them continue to perform congregational prayers.

In previous research conducted by [5], a device was created to assist deaf prayer follower in prayer. However, this device had shortcomings in that it could not be used by more than one prayer follower with disabilities, and its use was also limited to a short distance, making it almost impossible to cover the entire mosque. In addition, research conducted by [6] used the same device, which could assist deaf prayer follower in congregational prayer, but this device still had shortcomings, namely that the microwave sensor used could detect movements other than prayer movements, and the voice recognition module was very susceptible to noise.

In light of the shortcomings of the previous study, this study aims to develop a device or system that can help people with disabilities perform congregational prayers as an improvement on existing devices. The strap utilizes a Wireless Sensor Network system so that information can be broadcast to more than one node, thereby reaching several prayer follower with disabilities and expanding the range of this device. A Wireless Sensor Network, commonly abbreviated as WSN, is an integrated system device that contains one or more sensors equipped with a communication system [7]. A Wireless Sensor Network (WSN) is a collection of spatially distributed sensor devices used to monitor physical environmental conditions and transmit the collected information to a central location [8] In modern technology systems, WSNs are a critical component due to their low power consumption [9]. This low power consumption is a key feature of the node-based architecture in WSNs. Each node in a WSN consists of three main components: a radio transceiver for wireless communication, a microcontroller, and a power source [10].

The gyroscope sensor is used as an imam motion reader. This sensor will read changes in the X, Y, and Z angles, which will then be processed by Arduino Uno so that it can identify the various imam movements. As a novelty value from previous research, this study uses the LoRa SX1278 RA-02 module. LoRa stands for Long Range. The LoRa device is one of the leading transceiver devices in terms of wide range, low power consumption, and resistance to interference [10]. By using this module, the signal range increases and with a high communication spectrum and immunity to interference, the use of this module can mitigate blind spots and interference during communication.

This device also uses a DS3231 Real Time Clock (RTC) module, which provides real-time and continuous time data. This component was chosen because of its compact size [12], which maintains the compactness of this smart strap device for guiding people with disabilities in prayer. As its main output, this device uses a vibrator motor module that operates at a voltage of 2.8–3.2 V [13]. This device is used to notify deaf prayer follower when the imam changes his prayer movements.

II. METHOD

A. System Overview

The research conducted by researchers is research and development, which is a combination of quantitative and qualitative research approaches. The research and development method is a systematic approach in academia and industry that aims to produce innovations in the form of new products, systems, or models that are applicable or can also be interpreted as a research method used to produce certain products or tools and test the effectiveness of these products [14]. In another sense, Borg and Gall in [15] state that basic research methods are often used for needs analysis research so that hypothetical products can be produced. Furthermore, experiments or action research are used to test these hypothetical products. Once the product has been tested, it can be applied. Research and development are aimed at discovering, developing, and validating a product. In this study, the development carried out was in the form of a prayer guide tool for prayer follower with disabilities. The design of this tool uses a GY-25 sensor with LoRa SX1278 as a wireless transmission module.

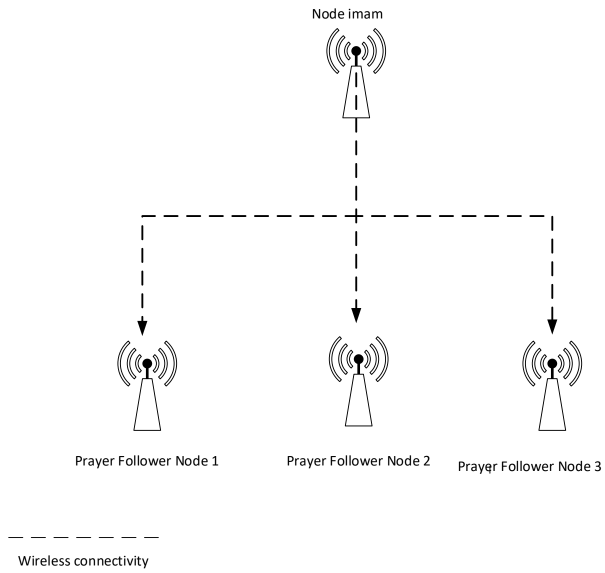


Figure 1 Multi-hop Wireless Sensor Network Topology

This system was created with a Wireless Sensor Network topology (Figure 1) with a total of 4 nodes. For the hardware implementation, 4 nodes will be provided, with 1 imam node equipped with a sensor to measure angle changes and a DS3231 Real Time Clock (RTC), and 3 nodes as prayer follower nodes.

The imam node functions to capture angle changes detected by the GY-25 MPU6050 gyroscope sensor [16] and detect every movement of the imam's prayer. This node is also equipped with a DS3231 Real Time Clock (RTC) module that determines prayer times based on the current time, allowing the device on the imam node to determine the number of rakaats to be performed. Figure 2 shows the block diagram of the imam node.

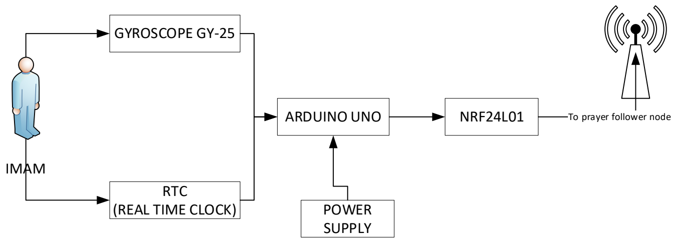


Figure 2 Block Diagram of the Imam Node

This prayer follower node functions as the last node that will provide notifications in the form of vibrations to prayer follower with disabilities. The device used as the output for vibrations is a coin vibrator motor module. This node is also equipped with an SX1278 RA-02 LoRa module to capture information transferred wirelessly, as well as an Arduino Pro Micro as a data processor. The block diagram for the prayer follower node is shown in Figure 3 as follows.

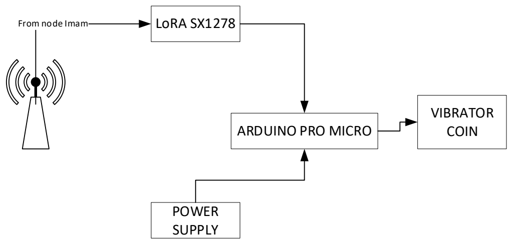


Figure 3 Block Diagram of the Prayer Follower Node

B. Hardware design

There are two types of devices, namely the Imam device and the prayer follower device. First, Figure 4 shows the circuit arrangement for the Imam device components. The Arduino Uno ATmega328 component functions as the Imam device controller, while the GY-25 MPU6050 gyroscope functions as a motion sensor and the LoRa SX1278 RA-02 component functions as a wireless module to transmit command signals.

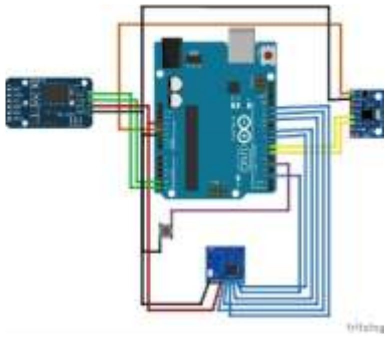


Figure 4 Circuit Connection of the Imam Node

Second, it is a component arrangement for devices on the prayer follower node. The circuit can be seen in the figure 5 which consists of an Arduino Pro Micro component as a data processor and prayer follower circuit controller, an SX1278 RA-02 LoRa module as a wireless signal receiver module, and a vibration motor module used to provide vibration notifications to the prayer follower when there is a change in the imam's movements.

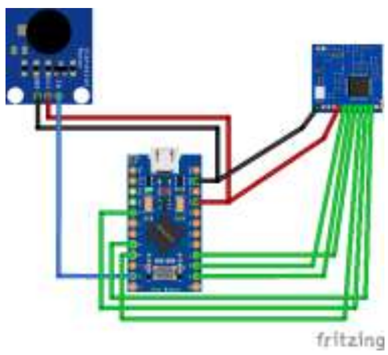


Figure 5 Circuit Connection of the Prayer Follower Node

C. Software Design

The software was designed by programming Arduino Uno ATmega328 and Arduino Pro Micro using Arduino IDE. The system consists of three main parts, namely input, process, and output with a Li-ion 18650 battery power supply as shown in Fig. 7.

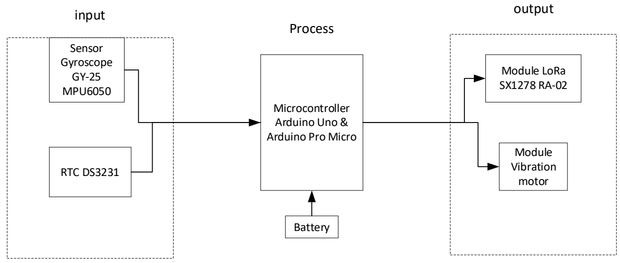


Figure 6 Software Design

On the input side, a GY-25/MPU6050 gyroscope sensor is used to detect changes in prayer movements (standing, bowing, standing upright, prostrating, and sitting), along with a DS3231 RTC module to provide real-time data used to determine prayer times and the number of raka'at. The data from the sensor is then processed by an Arduino Uno to identify the movement status and transmit it via the LoRa SX1278 RA-02 wireless module. On the follower's side, the data is received by an Arduino Pro Micro via the LoRa SX1278 RA-02 module, which is then processed to control a vibration motor as a notification actuator in the form of vibrations. Variations in vibration patterns, as shown in Table I, are used to distinguish each prayer movement.

TABLE I
VARIATION OF VIBRATION PATTERN

Movements	Vibration variation	explanation
Standing, i'tidal	—	One long vibration
Bowing/ruku	●●	Two short vibrations
Prostrating	— —	Two long vibrations
Sitting between prostrating, sitting for tasyahud	●●●	Three short vibrations
Salam	— — —	Three long vibrations

Table I shows that the vibration patterns are grouped into prayer positions that share the same basic posture—such as the i'tidal and standing positions, which both involve standing upright, or the first and second prostrations, which both involve prostration—as well as the sitting position. This is intended to minimize the need for deaf or visually impaired worshippers to memorize numerous vibration patterns.

D. Flowchart system

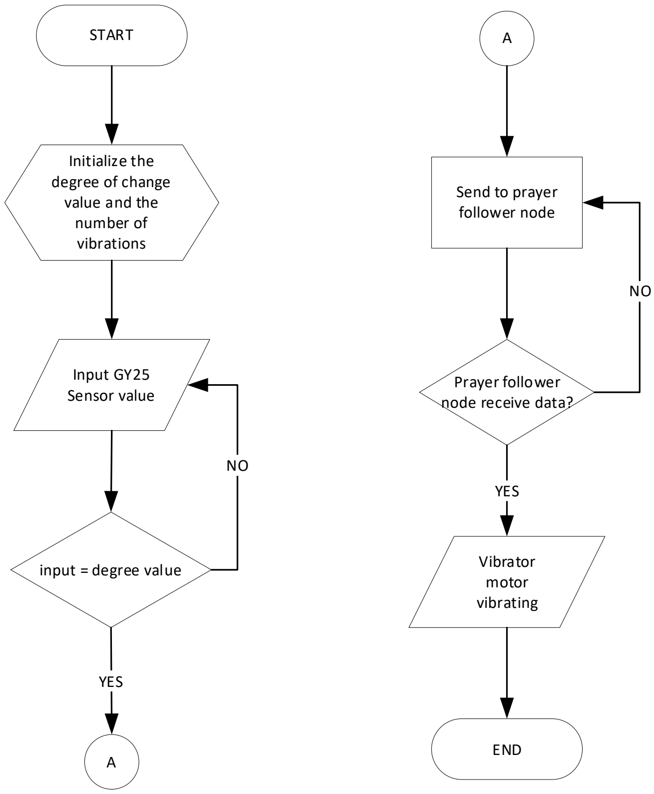


Figure 7 Flowchart System

Figure 7 above explains how this device identifies the imam's movements and sends the data to the prayer follower node. The system begins by initiating the degree of change for each movement and vibration. The data used in this initiation stage is obtained from a certain number of tests on the imam node for each prayer movement so that the imam node test data can be used to obtain the range of angle changes as the initial value for the imam's angle change variable. as well as vibrations. The next stage is sensor value input. The system will then decide whether the value input by the sensor is the same as the previously initialized value. If not, it will return to the sensor value input stage. If yes, it will proceed to the next stage, which is sending data to the broadcast node wirelessly. If the data is received by the broadcast node, it will be forwarded to the prayer follower node. If not, it will return to the data sending stage. The data sent from the broadcast node will be processed into a vibration output according to the number of vibrations that have been initiated in accordance with the prayer movements.

E. System Testing Methods

In this study, the system that has been developed will be tested on people with hearing and visual impairments, therefore it requires an appropriate method so that people with hearing and visual impairments can understand it. The method used in this study is learning by training. This method was chosen so that the device can function properly when users understand the instructions given by the device and not only understand but also memorize all the instructions given by the device.

This method is implemented so that people with hearing and visual impairments will learn and memorize how the tool works through training. Technically, the training will be assisted by people who are experts and accustomed to communicating with people with hearing or visual impairments.

III. RESULT AND DISCUSSION

A. Implementation of The Imam Node

In the Imam node shown in Figure 8, the components used are Arduino Uno as the microcontroller and main data processor for the other components, the GY -25 gyroscope sensor to measure angular changes during prayer movements, an RTC (Real-Time Clock) module to determine prayer times and calculate the number of prayer cycles to be performed, and a LoRa SX1278 RA-02 module for wireless communication. The power source for this device is an 18650 li-ion battery. This device uses a strap to attach it to the imam's chest. Placing the device on the imam's chest is intended to provide more consistent angle readings than placing it on the imam's hand.

Figure 8 Result of implementation Imam Node

B. Implementation of the prayer follower node

The prayer follower node shown in Figure 9 is an end-user that contains the output of data processed by the Arduino Pro Micro microcontroller and sent via the LoRa SX1278 RA-02 module on the imam node and broadcast node. The components in this node are the Arduino Pro Micro microcontroller, the LoRa SX1278 RA-02 module along with the LoRa SX1278 RA-02 adapter used to regulate excess voltage from the Arduino Pro Micro digital pin output, a vibration motor module, and an 18650 Li-ion battery as the power supply.

Figure 9 Implementation of prayer follower node

C. *Signal range testing*

This test was conducted to examine the signal transmission and reception capabilities based on the range produced by the LoRa SX1278 RA-02 module. The LoRa settings used are as follows:

- Frequency : 433MHz
- TX Power : +14 dBm
- Bandwidth : 125 kHz
- Spreading factor : 7

This test was conducted at the At-Taqwa Mosque in Bangkalan, Jl. KH. Moh. Kholil No.31, Demangan, Bangkalan District, Bangkalan Regency, East Java. The mosque covers an area of 336 square meters, with a length of 24 meters and a width of 14 meters.

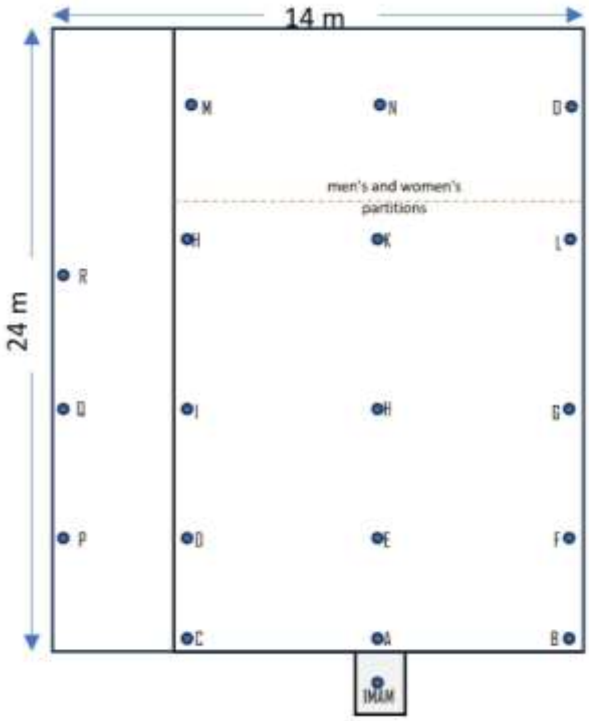


Figure 10 signal testing point layout

TABLE 1
SIGNAL RANGE TESTING

Conditions	Distance	RSSI	SNR
Point A	2 meters	-92	8,50
Point B	5 meters	-97	8,50
Point E	5 meters	-97	8,25
Point C	6 meters	-98	8,25
Point D	9 meters	-101	7,50
Point F	9 meters	101	7,50
Point H	10 meters	-107	4,25
Point G	12 meters	-111	-2,75
Point I	12 meters	-106	5,50
Point P	13 meters	-101	7,75
Point Q	15 meters	-109	-2,75
Point K	16 meters	-110	-1,50
Point J	18 meters	-111	-3,75
Point L	18 meters	-111	-4,25
Point R	18 meters	-104	5,25
Point N	25 meters	-111	2,00
Point M	27 meters	-109	3,75
Point O	27 meters	-112	0,75

This test was conducted at several different points (figure 10) throughout the mosque to assess signal reception quality. RSSI and SNR indicators were used to measure signal reception quality. RSSI (Received Signal Strength Indicator) is an indicator of the signal strength received by wireless devices in dBm units. The closer to 0, the better the signal. SNR (Signal to Noise Ratio) is a measurement of signal quality that compares signal strength to noise in dB units.

From the data obtained in Table II, it can be seen that the signal from the Imam node can be received at all test points or can reach all mosques, but as the test distance increases, the signal quality decreases. as evidenced by the RSSI value at a distance of 5 meters being -97 dBm and the SNR value being 8.5, while at a distance of 12 meters, the RSSI and SNR values drop to -112 dBm and 5.50 dB, as shown in the figure 11 below.

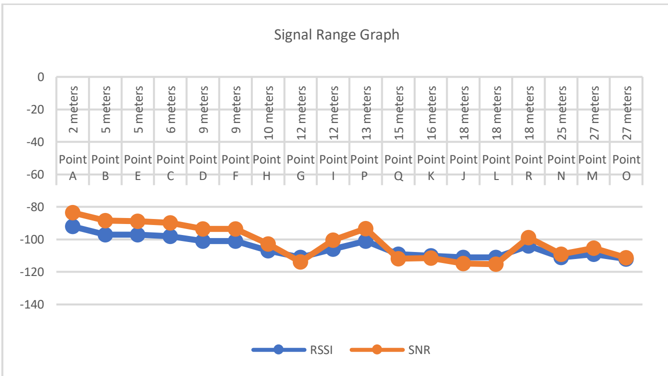


Figure 11 Signal Quality Over Distance

In addition, the position of the imam also affects signal reception quality. For example figure 12, points G and I are both 12 meters away, but their RSSI and SNR values are different. At point G, the RSSI value is -111dBm and the SNR value is -2.75 dB. Meanwhile, at point I in the image, the RSSI value is -106 dBm and the SNR is 5.50 dB.

Figure 12 Signal Quality When Prostrating and Bowing

This difference is caused by the different positions of the imam at point G, where the imam is in a prostration position, so the signal transmitter is in a more enclosed space due to the imam's prostration position, whereas at point I, the signal transmitter at the imam node is in a more open space.

D. Angel Change Testing

The data on the angle changes was obtained by collecting data from two people with different body postures. The first person was 150 cm tall, and the second person with a height of 165 cm. This was done to determine the angle range for each condition during prayer (standing, bowing, standing upright, first prostration, sitting, second prostration, and sitting for the final testimony), as well as to find out whether body posture affects the angle readings. The data used was the data obtained from reading the angle changes on the Y-axis or pitch will displayed in a table IV.

TABLE IV
DATA OF ANGLE CHANGE

	150 cm tall	**165 cm tall**
Standing	(-3,35) - (18,54)	(-4,63) - (10,25)
Bowing	(60,21) - (70,5)	(47,47) - (69,76)
Standing Upright	(-1,03) - (17,1)	(3,16) - (11,46)
Prostration	(89,17) - (155,44)	(88,77) - (101,2)
Sitting	(-16,65) - (6,19)	(-3,8) - (9,17)
Testimony	(-12,32) - (0,37)	(3,4) - (9,57)

The difference in value for each movement of prayer (standing, bowing, standing upright, prostrating, and sitting) can be described as follows.

Standing, the range of degrees for an imam with a height of 150 cm is -3° – 18°, while for an imam with a height of 165 cm it is -4° – 10°. Therefore, the difference between the two is 6°. Rukuk, the angle range for an imam with a height of 150 cm is 60° – 73°, while for an imam with a height of 165 cm it is 47° – 69°. Therefore, the difference between the two is 9°. I'tidal, the degree range for an imam with a height of 150 cm is -1° – 17°, while for an imam with a height of 165 cm it is 3° – 11°. Therefore, the difference between the two is 10°. Sujud, the angle range for an imam with a height of 150 cm is 89° – 155°, while for an imam with a height of 165 cm it is 88° – 101°. Therefore, the difference between the two is 53°. Sitting, the degree range for an imam with a height of 150 cm is -16° – 6°, while for an imam with a height of 165 cm it is 3° – 9°. Therefore, the difference between the two is 16°.

Based on the above difference data, it is evident that the height of the imam affects the angle reading of each prayer movement performed. However, to overcome this difference in values, it is necessary to adjust the value range in the Arduino program code, namely by finding the smallest and largest degree values for each prayer movement for both imams, so that when this smart strap prayer guide device is used by imams who are 150 cm or 165 cm tall, it can still read each prayer movement performed.

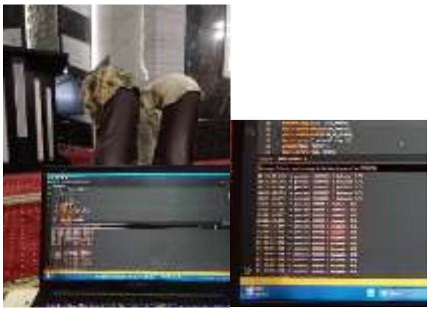
E. Motion detection testing

The testing of this prayer movement detection device is divided into two parts. The first part tests the capture of movements for each number of rakats in prayer, starting from 2 rakats, 3 rakats, and 4 rakats. Testing each number of rakats in prayer aims to determine whether this device can function with different numbers of rakats according to the type of prayer performed, namely 2 rakats for the Fajr prayer, 3 rakats for the Maghrib prayer, and 4 rakats for the Zuhr, Asr, and Isha prayers. To facilitate the reading of the test results, one of the devices on the prayer follower is connected to a serial monitor on the laptop fig 13.

Figure 13 Motion Detection Testing

For samples from the prayer motion detection test for 2 rakaats, the results will be displayed in a table V

TABLE V
RESULT OF MOTION DETECTION TESTING

No	prayer position	Testing photo
1	Standing, first rakats	
2	Bowing, first rak'ah	
3	Standing up straight, first rakats	
4	Prostration, First rakats	
etc	etc	

This test proves that this device can be used for all numbers of rakats in accordance with the stipulated number of rakats for each prayer time, starting from 2 rakats for the fajr prayer, which consists of 14 motions from standing to greeting. 3 rakats for the Maghrib prayer, which consists of 21 motions from standing to greeting, and 4 rakats for the Zuhr, Asr, and Isha prayers, which consist of 27 motion from standing to greeting.

The second part tests the reliability of the device. This smart strap prayer guide device for people with disabilities will be tested to read the imam's prayer movements several times to determine the device's capabilities and error percentage. In this test, the device will be tested 20 times with a total of 2 rakaats fig. 14.

Figure 14 Reliability Testing

The result of reliability testing are shown in the table VI.

TABLE VI
RELIABILITY TESTING

experiment	Function Result from Standing to Greeting		
	Follower 1	Follower 2	Follower 3
1	✓	✓	✓
2	✓	✓	✓
3	✓	✓	✓
4	✓	✓	✓
5	✓	✓	✓
6	✓	✓	✓
7	✓	✓	✓
8	✓	✓	✓
9	✓	✓	✓
10	✓	✓	✓
11	✓	✓	✓
12	✓	✓	✓
13	✓	✓	✓
14	✓	✓	✓
15	✓	✓	✓
16	✓	✓	✓
17	✓	✓	✓
18	✓	✓	✓
19	✓	✓	✓
20	✓	✓	✓
Success rate	100%	100%	100%
Average success rate	100%		

The results of the tool reliability test were measured using percentage units. The average success rate of capturing movement and performing vibration notification on the prayer follower node was 100%. The average signal capture value on prayer follower nodes 1, 2, and 3 after testing 20 times with a total of 2 rakaats was 100%, with prayer follower node 1 at 100%, prayer follower node 2 at 100%, and prayer follower node 3 at 100%.

IV. CONCLUSION

The design of a prayer guide strap for deaf or blind people was successfully created by combining the MPU6050 GY25 and LoRa SX1278 RA-02 sensors. The GY25 gyroscope sensor was successfully implemented and worked well as a reader of the imam's prayer movements by measuring angular changes in the Y axis or pitch. The RSSI value obtained using the LoRa SX1278 RA-02 module at a distance of 27 meters was -109 dBm with an SNR value of 3.75 dB. From this study, it can also be concluded that differences in the height of the imam can affect the reading of the GY25 sensor angle value, so it is necessary to adjust the range in the Arduino program code. The prayer follower node can function very well to respond to every prayer movement made by the imam through notifications in the form of vibrations from the vibration motor, this shows that the tool that has been made works according to its purpose to align the movements of the deaf prayer follower with the movements of the imam. This is also supported by data obtained through testing which shows an average success rate of 100% from the 3 tested prayer follower nodes.

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