International Journal of Robotics and Control Systems
Vol. 3, No. 4, 2023, pp. 899-910
ISSN 2775-2658
http://pubs2.ascee.org/index.php/ijrcs

Implementation of LoRa Wireless Communication in Smart Diabetic Shoes Design

Purwono [a,1,*], Asmat Burhan [a,2], Lutviana [a,3]

[a] Universitas Harapan Bangsa, Purwokerto, 53182, Indonesia
[1] purwono@uhb.ac.id; [2] asmatburhan@uhb.ac.id; [3] luthvianna41@gmail.com
* Corresponding Author

ARTICLE INFO

Article history
Received September 05, 2023
Revised November 18, 2023
Accepted November 20, 2023

Keywords
Diabetes;
Lora;
Sensor;
Wireless

ABSTRACT

Diabetes is a widespread medical condition affecting a substantial portion of the global population. It is a metabolic disorder known as diabetes mellitus, characterized by severe fluctuations in blood glucose levels due to inadequate insulin production in the human body. The effective monitoring of diabetes is of paramount importance to researchers as it holds the potential to enhance the quality of healthcare services. Among the challenges faced by individuals with diabetes, one prevalent issue is the development of ulcers, which can be challenging to detect promptly. Technological advancements offer a promising avenue for cost-effective and continuous monitoring of chronic diseases like diabetes. This study centers on the development of IoT-based intelligent diabetic footwear that incorporates pressure sensors and temperature monitoring for individuals with diabetic feet. In the evaluation of SX1278 (Ra-02) Lora Module communication, deployed at eight different locations, it was observed that two of these points achieved a flawless transmission success rate of 100%. Conversely, the communication failed at points 6 and 7, with a success rate falling below 50%. Some of these failures can be attributed to signal obstructions, including natural elements such as trees and terrain, as well as man-made structures like buildings and machinery workshops, which hinder the efficient transmission of signals from the end node to the gateway. The results of this research provide positive implications in the form of developing IoT-based diabetes shoes that can be applied with alternative Lora communication connections in areas with poor internet signal.

1. Introduction

Diabetes is a widespread condition that impacts a significant portion of the population. This is evident from the data, which predicts an increase in the number of individuals affected, projected to grow from 537 million in 2021 to 783 million by 2045 [1]. This ailment represents a substantial menace to the overall well-being of the global population [2]. Diabetes mellitus is a metabolic dysfunction that manifests when a person's body produces insufficient insulin, leading to exceptionally elevated blood glucose levels [3]. There are a minimum of 40 diabetes variants, and it seems that people across the globe lack awareness of the complications stemming from healthcare systems that lack adequate resources [4].

The impact of diabetes also extends to the economic sector in society. Expenditure on the treatment of this disease is on the rise, increasing from $966 billion in 2021 to a projected value of over $1 trillion in 2045 [5]. This, of course, also has an impact on indirect costs, such as reduced levels of productivity among those who suffer from it. As reported by the official website of the Ministry of Health, in 2021, Indonesia was ranked 5th out of 10 countries with the highest number of diabetes cases in the world. The increasing number of diabetes patients in Indonesia is an important issue that necessitates improved access to healthcare services [6].

In accordance with international and national guidelines, self-management of the disease and the achievement of optimal quality in diabetes control, as well as disease prevention efforts, are accomplished through patient education in blood glucose management [7]. Prevention can also be achieved by monitoring glucose levels in the body three times a day [8].

The era has witnessed the continuous advancement of technology, giving rise to innovations in the form of new media designed to enhance the daily lives of humans [9]. Various types of technology focused on diabetes include glucose monitoring, continuous subcutaneous insulin infusion, closed-loop systems, electronic teaching, applications for smart devices, and automated bolus calculators [7]. These technologies can apparently be integrated with the Internet of Things (IoT) [10]. Diabetes can be monitored at any time within a 24-hour period by utilizing sensors integrated into the IoT [11].

Monitoring diabetes is a significant concern for researchers as it can be instrumental in enhancing the quality of the nursing service system [12]. It is known that the traditional method of pricking the fingertip to check glucose levels can induce psychological distress in patients and may lead to infections [8]. This certainly motivates researchers to develop various types of tools that are more effective for monitoring this disease.

One of the common conditions in diabetic patients is ulceration which is difficult to detect in a timely manner [13]. Diabetic feet are very at risk of injury, infection to ulceration in patients [14]. This condition is also exacerbated by the high risk of recurrence of diabetic foot. This recurrence is caused by abnormal lower extremity movements and changes in plantar biomechanics. Excessive foot pressure also results in damage to the skin on the soles and instep, thus compromising the patient's condition which has the potential for ulcer recurrence and amputation [14].

Technological advances open up new opportunities for nursing concepts and improving digital-based health services [15]. Technology can minimize the total cost of continuously and timely monitoring chronic diseases such as diabetes [16]. Additionally, with the widespread accessibility of smartphones and fast Internet, patients are increasingly using mobile applications to manage various medical requirements [15]. IoT is continuously evolving as a monitoring tool for a wide range of critical data through the utilization of sensors [17].

Research on IoT continues to grow rapidly. The IoT framework consists of a network of interconnected devices, sensors, and systems that communicate and share data [18]. The Internet of Things (IoT) represents a concept or scenario in which objects can relay information over a network without the need for human-to-human or human-to-computer interaction [19].

Several researchers, including Ganesh [20], have applied special IoT-based diabetic foot monitoring technology, implementing cost-effective monitoring of foot pressure and blood flow with wireless communication to collect real-time data for analysis by doctors. Similar research has also been conducted by Eskofier, who developed smart shoes for diabetes, offering possibilities to support prevention, diagnostic screening, and therapeutic decisions [14]. Kularathne's research resulted in an innovative plug-and-play mobile-based device that can be applied to any type of diabetic shoe, addressing foot ulcers, monitoring temperature, humidity, weight, and step count to prevent breakdown [21].

Indonesia, being a country with relatively low internet speed, faces challenges in fully implementing IoT [22]. Many areas still suffer from poor connectivity. Implementing IoT-based diabetes shoes in areas with slow internet connections remains a challenge.

Our contribution in this research is to propose a prototype design for smart shoes by utilizing Lora communication as a transmitter and receiver of pressure and temperature sensor data for diabetic foot ulcer sufferers. Lora selection is considered as a new alternative in data communications, especially in areas with unstable internet signals.

Our research addresses a critical challenge: the implementation of IoT-based diabetic footwear in areas with poor internet connectivity. We present the development of smart diabetes shoes integrated with the Lora module, offering a solution to underutilized wireless communication connections [23]. This paper outlines the methodology and findings of our study, shedding light on the potential for IoT technology to improve diabetes management in resource-constrained regions.

2. Diabetic Foot Ulcer Indicator

2.1. Temperature

Diabetic Foot Ulcers (DFU) are characterized by an increase in temperature on the skin of the patient's feet, resulting from inflammation and autolytic enzymatic tissue breakdown due to an imbalance in pressure activity, repeated stress, neuropathic sensory loss, and biomechanical abnormalities [24]. An increase in temperature on the patient's feet exceeding 2.2ºC can serve as an indicator of the imminent risk of ulcers [25]. Skin thermometry can be employed as a tool to identify early signs of inflammation, preventing DFU occurrences and reducing the potential for severe complications that may lead to amputations or even death [26].

There isn't a specific range available to measure this condition because the body temperature varies greatly among individuals who suffer from it [27]. This issue can be addressed by comparing one part of the body with its symmetrical counterpart under normal conditions [28]. Elevated temperature in the diabetic foot area, along with local pressure, can worsen the patient's wound condition. Several researchers have utilized thermometry as a diagnostic tool to detect hidden neuropathic fractures in diabetic patients [22].

2.2. Pressure

Pressure plays a major role in the condition of patients suffering from diabetic foot [29]. Elevated plantar pressure exerts additional stress on the underlying soft tissue, leading to tissue damage and ulceration [30]. The midfoot is the most common location for the highest plantar pressure [31]. A significant body of literature demonstrates an association between ulcer formation and increased foot pressure [17]. In a study conducted by Altayyar, it was revealed that foot pressure is also influenced by the patient's weight [32]. Generally, men have higher plantar pressure than women in this context because men tend to weigh more than women [28].

3. Technology Investigation and Selection

3.1. Pressure Sensor

Force Sensing Resistors (FSRs) are two-terminal devices produced using polymer blends and conductive nanoparticles [33]. FSRs have gained significant recognition in research circles owing to their remarkable piezoresistive characteristics. When an FSR experiences mechanical loading, it undergoes a change in resistance, which can be inversely correlated with the applied force or stress. This phenomenon is commonly referred to in the literature as negative piezoresistive behavior.

The pressure sensor used is the RFP602 Force Sensing Resistors resistance type which is waterproof, thin film which is flexible and made with nanometer pressure sensitive material equipped with an ultrathin film substrate. The operational method for this sensor involves transforming the stress applied to a sensitive area into a two-line resistance variation. By utilizing the declared relationship between stress and resistance, it becomes possible to gather information about changes in stress from external sources. Notably, as stress levels increase, the sensor's output resistance decreases. The specifications of this sensor are:

1. Model: RFP-602
2. Sensitive Area Diameter: 10mm
3. Measuring Range: 10-500g
4. Material: PE insulating plate
5. Sensor thickness: 0.2mm
6. Working temperature: -25 ° C ~ 70 ° C

3.2. Temperature Sensor

The pressure sensor used is DHT11. The sensor is a sensor module designed to detect temperature and humidity in objects [34]. It provides an analog voltage output, which can be subsequently processed by a microcontroller. This sensor module falls under the category of resistive elements used in temperature measurement, similar to NTC (Negative Temperature Coefficient) sensors, for instance [35].

3.3. LoRa SX1278

LoRa is an IoT-enabling technology that is particularly well-suited for low data rate applications [36]. Through wireless modulation, LoRa facilitates remote communication for end nodes, while LoRaWAN refers to the communication protocol and system architecture. The key distinguishing feature of LoRa from other available wireless WAN technologies is its ability to transmit over long distances with minimal power consumption [37]. LoRa supports low bit rate applications with less emphasis on mobility and reliability. It was developed to support wide area network wireless telecommunications, and it's recognized as an alternative for IoT [38].

LoRa can function as both a transmitter and a receiver [39]. This versatility makes it highly intriguing for application in various research fields. The SX1278 transceivers incorporate the LoRaTM long-range modem, offering exceptional spread spectrum communication with extended range and robust interference resistance, all while keeping power consumption to a minimum. Utilizing Semtech's patented LoRaTM modulation technology, the SX1278 can achieve remarkable sensitivity of over -148dBm, even with cost-effective components like a low-cost crystal and bill of materials. This impressive sensitivity, coupled with the built-in +20 dBm power amplifier, results in an industry-leading link budget, making it an ideal choice for applications requiring extensive range or robust performance. LoRaTM also presents notable advantages in terms of both blocking and selectivity when compared to traditional modulation techniques. This resolves the traditional design trade-off between range, interference immunity, and energy efficiency.

3.4. NodeMCU

In this research, we have employed NodeMCU as the microcontroller of choice. NodeMCU Esp8266 is an open-source, programmable module that includes an integrated Wi-Fi card, designed for the development of IoT projects [40]. NodeMCU is outfitted with various peripherals that enable communication with the external environment, including 10 GPIO pins, an analog pin, and a dedicated communication pin [41].

The FSR sensor generates input data, which is subsequently transmitted via the Lora SX1278 module and received by the designated receiver. NodeMCU was chosen for its user-friendly capability to link sensor-generated data as a web server, streamlining the process for IoT developers to showcase sensor data through client applications such as websites or mobile apps [42].

4. Method

The goal of this research is to monitor the condition of patients with diabetic foot. Smart diabetes shoes are a type of diabetic footwear integrated with multiple sensors and IoT-supporting modules. These shoes include a pressure sensor to measure the pressure on the feet of diabetic patients and a temperature sensor to monitor the temperature of their feet. We have developed an IoT-based system that utilizes LoRa technology as a communication tool, serving as both a transmitter and receiver.

This system can serve as an alternative IoT connection in areas with poor internet signals. The system's design is illustrated in Fig. 1.

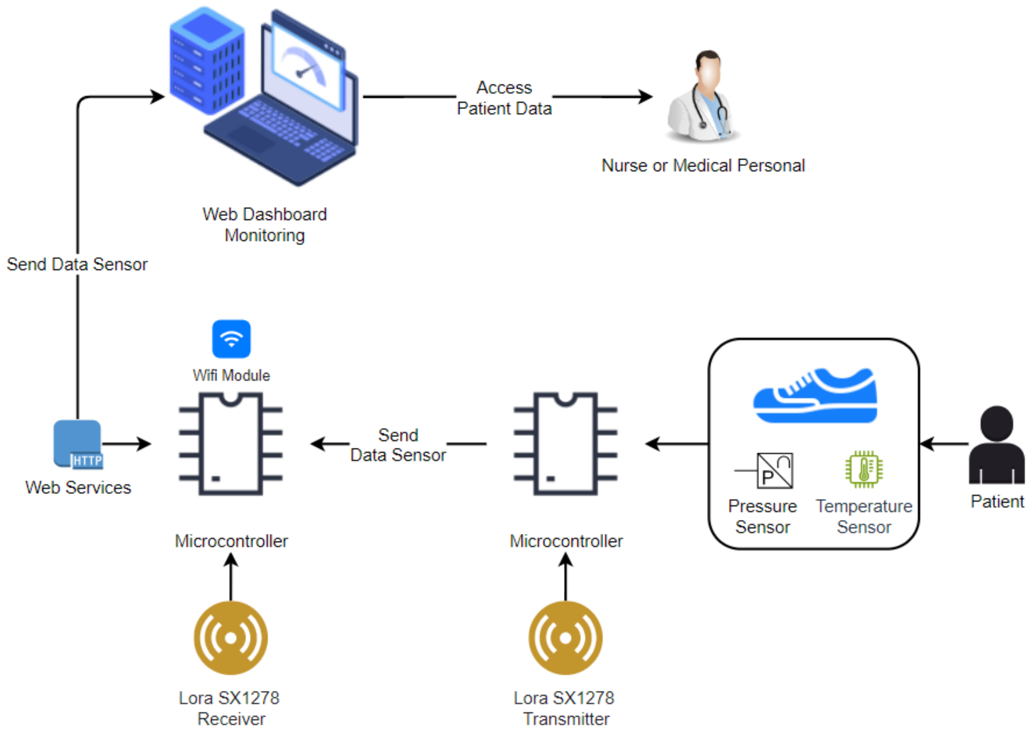

Fig. 1. System flow

Based on Fig. 1, the Smart Diabetic Shoe functions from the patient's end, transmitting pressure and temperature sensor data using the LoRa transmitter module. This sensor data is subsequently received by a receiver employing NodeMCU, which then stores the data in the database. The stored data is processed through web services, enabling it to be displayed on the web client as monitoring media. Smart diabetic shoes serve as a media transmitter utilizing the SX1278 module. This module sends pressure sensor data and patient temperature to the media receiver. Specifically, the pressure sensor is positioned in the middle of the shoe, adhering to the recommendations from Wibowo's research. When humans stand upright, the two hind feet bear approximately 60% of the body's weight. In this study, three main points will be tested, as depicted in Fig. 2.

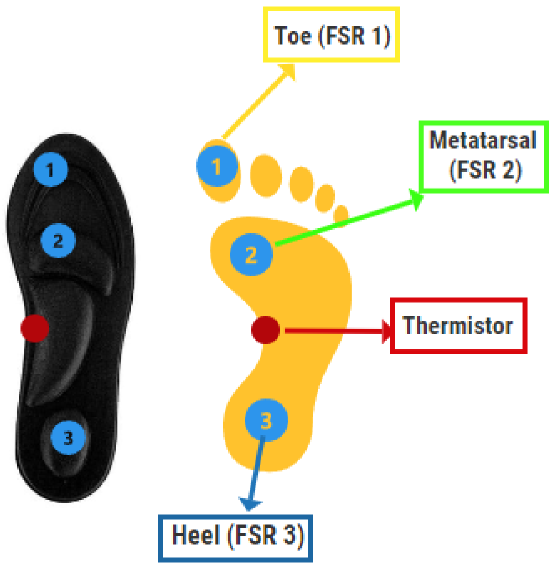

Fig. 2. Foot pressure sensor point

The prototype for this media transmitter incorporates the following components: one NodeMCU, four distinct pressure sensors, a single temperature sensor, and a LoRa SX1278 module, all utilized for the transmission of sensor data. The media receiver employs solely a NodeMCU and a LoRa SX1278 module. This receiver acquires pressure and temperature sensor data transmitted by smart diabetic shoes. NodeMCU functions as a web server, subsequently presenting the sensor data on the client's web application.

In this study, testing and validation of the FSR sensor and thermistor sensor were conducted through calibration. Calibration is the process of comparing a tool or measurement instrument with standards set either nationally or internationally. The aim of calibration is to assess the degree to which the accuracy and reliability of the measurement tool yield results that align with established standards. Equation (1) serves as a method for calibrating the FSR sensor.

$$F = P * A \tag{1}$$

Where F is the force given in Newtons (N), P is the resulting pressure in kilopascals (kPa), and A is the area over which pressure is applied in square meters (m^2).

Regarding the calibration test of the thermistor sensor, it is conducted by comparing it with a digital thermometer, and each sensor is calibrated within a timeframe of 3 to 30 seconds. The calibration result data is then recorded based on the differences.

Communication tests involving the use of the LoRa SX1278 module to transmit pressure and temperature sensor data from the smart diabetes shoes were performed at a maximum distance of approximately 2.2 km in the Gumelar District, Banyumas Regency. This study divided the testing into several points located where healthcare workers are active. There are 8 location testing points for media receivers, each of which encounters various obstacles in its area. These locations are adjusted to the positions of active healthcare workers in Gumelar Sub-District, including village midwives, village health posts (PKD), health centers, and doctors.

NodeMCU serves as an intermediary capable of storing data received by the LoRa SX1278 module into a database server. The stored sensor data is subsequently processed using the HTTP protocol to facilitate communication between the server and the client. This study utilizes the GET request method to enable data to be displayed on a web client application developed using the PHP programming language.

5. Result and Discussion

5.1. Smart Diabetic Shoe Prototype

The implementation of pressure and temperature sensors is proceeding smoothly. Pressure sensors have been positioned on the underside of the diabetic shoe at three crucial points: the front, middle, and rear of the foot [43]. Fig. 3 illustrates the placement of the pressure sensor on specialized diabetes shoes. All the essential components, including the pressure sensor, temperature sensor, and the Lora SX1278 module installed on the NodeMCU, have been successfully assembled. The hardware wiring process has been completed without any issues.

5.2. Sensor Test

The measurement of pressure on the FSR is not directly correlated with a person's weight but is rather linked to load distribution and the sensitivity characteristics of the FSR. The calibration process is conducted to establish a relationship between the pressure recorded on the FSR and the individual's weight. Based on Table 1, testing was carried out from the 3rd to the 30th second. Between the 3 FSR sensors that have been installed, simulations are carried out with a minimum pressure equivalent to 500 grams. The results show relatively consistent differences for the FSR1 and FSR2 sensors, but different variations are observed for the FSR3 sensor, ranging from 0.02 kPa to 0.13 kPa. Specifically, for the FSR 3 sensor, there are 3 results which are considered to produce quite different and less consistent values, namely the difference in values at time 15, 21, 27 and 30 with respective values, namely 0.07 kpA, 0.02 kpA, 0.02 kpA and 0.13kpA. This is deemed necessary for further research regarding the finding that there are inconsistencies for the FSR 3 sensor.

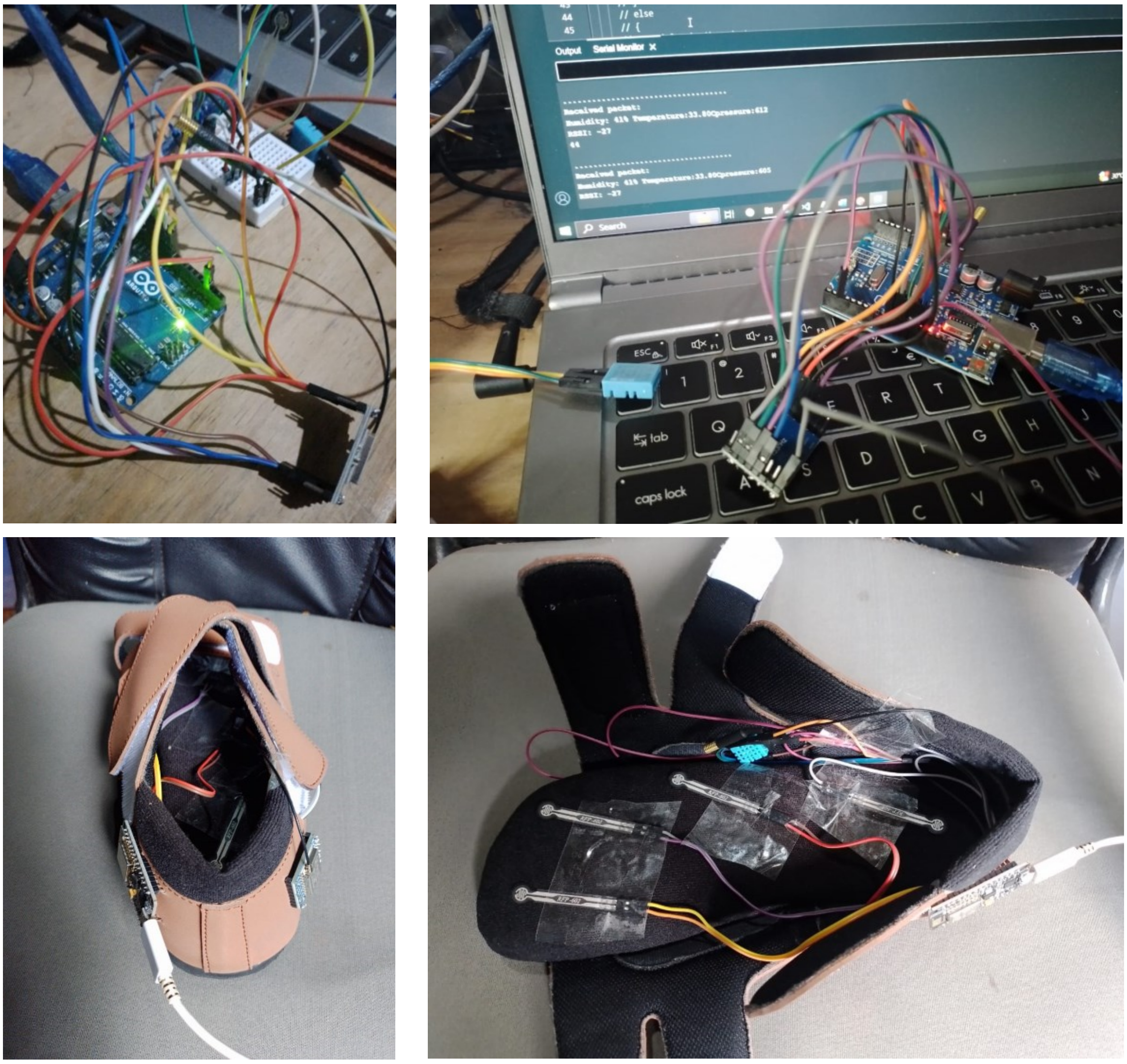

Fig. 3. Prototype smart diabetic shoe

Table 1. FSR sensor calibration

Time	Simulation (500g)	FSR1	FSR2	FSR3	Difference FSR1	Difference FSR2	Difference FSR3
3	4.79kpA	5.00kpA	5.00kpA	5.00kpA	0.21kpA	0.21kpA	0.21kpA
6	4.79kpA	5.00kpA	5.00kpA	5.00kpA	0.21kpA	0.21kpA	0.21kpA
9	4.79kpA	5.00kpA	5.00kpA	5.00kpA	0.21kpA	0.21kpA	0.21kpA
12	4.79kpA	5.00kpA	5.00kpA	5.00kpA	0.21kpA	0.21kpA	0.21kpA
15	4.79kpA	5.00kpA	5.00kpA	4.72kpA	0.21kpA	0.21kpA	0.07kpA
18	4.79kpA	5.00kpA	5.00kpA	5.00kpA	0.21kpA	0.21kpA	0.21kpA
21	4.79kpA	5.00kpA	5.00kpA	4.77kpA	0.21kpA	0.21kpA	0.02kpA
24	4.79kpA	5.00kpA	5.00kpA	5.00kpA	0.21kpA	0.21kpA	0.21kpA
27	4.79kpA	5.00kpA	5.00kpA	4.81kpA	0.21kpA	0.21kpA	0.02kpA
30	4.79kpA	5.00kpA	5.00kpA	4.92kpA	0.21kpA	0.21kpA	0.13kpA

Based on Table 2, the calibration of the thermistor sensor is also conducted from the 3rd to the 30th second. Over the course of the 30-second experiment, the difference between the digital thermometer and the thermistor appears to remain relatively constant and is still considered acceptable as a test calibration result, approximately ranging from 0.3°C to 0.4°C.

Table 2. Thermistor sensor calibration

Time	Digital Thermometer	Thermistor	Error Value
3	24.0C	24.04C	0.4C
6	24.0C	24.04C	0.4C
9	24.0C	24.04C	0.4C
12	24.0C	24.04C	0.4C
15	24.0C	24.03C	0.3C
18	24.0C	24.04C	0.4C
21	24.0C	24.03C	0.3C
24	24.0C	24.04C	0.4C
27	24.0C	24.02C	0.2C
30	24.0C	24.03C	0.3C

5.3. Lora Communication Test

Data transmission was carried out at eight points in the distribution area for health workers in Gumelar District. This is done to determine whether data transmission can be optimized at a predetermined point, with several attempts made until success is achieved at least three times. Data during testing was monitored using the Arduino Uno console terminal on a device connected to the smart diabetes shoe prototype which can be seen in Fig. 4. Table 3 shows that the two test points achieved a 100% success rate in sending data. LoRa communication failures occur at points 6 and 7, with the success rate dropping below 50%. Some of these failures are caused by signal obstructions, such as trees, high ground, buildings, and machine shops, which cause reduced signal absorption from the end node to the gateway. As a result of this failure, the technology for using the Lora SX1278 still needs to be researched further because we have not been able to get good and effective data transmission accuracy results. Further research efforts are needed so that the proposed technology can really be implemented well.

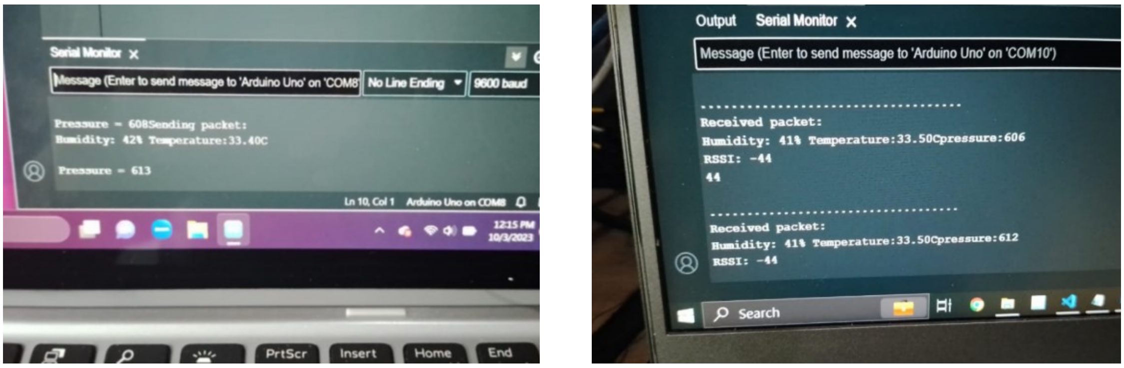

Fig. 4. Sending and receiving lora data test

Table 3. Lora transmitter and receiver experiment results

Point	Distance (m)	Level of success	Location	Obstacle
1	600	80%	PKD Tipar	Trees, Highlands
2	434	100%	Bidan Grumbul Sumber	Trees, Highlands
3	1230	100%	Bidan Grumbul Sompok	Trees, Highlands
4	1780	60%	Dokter Retno	Trees, Highlands, Buildings, Machine Workshops
5	1720	65%	Bidan Gumelar	Trees, Highlands, Buildings, Machine Workshops
6	4345	40%	Bidan Samudra	Trees, Highlands, Buildings, Machine Workshops
7	5440	30%	Bidan Cilangkap	Trees, Highlands, Buildings, Machine Workshops
8	2200	80%	Puskesmas Gumelar	Trees, Highlands, Buildings, Machine Workshops

5.4. Web Client Test

NodeMCU is employed as an intermediary for storing data received by the LoRa SX1278 module into a database server. The stored sensor data is subsequently processed using the HTTP protocol to enable communication between the server and the client. This study utilizes the GET request method to enable data to be displayed on a web client application built with the PHP programming language. Fig. 5 displays the user interface of the web client for the smart diabetes shoe application, which can be used to monitor the pressure and temperature of patients with diabetic feet.

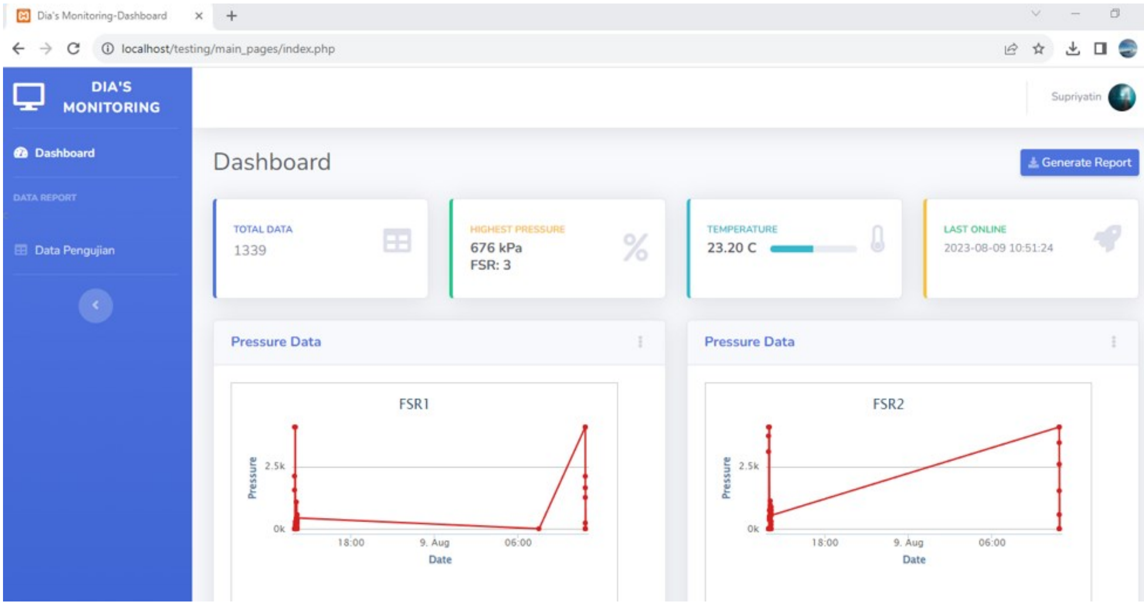

Fig. 5. Web client test

6. Conclusion

This research has succeeded in building an IoT-based diabetic shoe prototype that utilizes lora communication to monitor the compressive force and temperature of diabetic feet sufferers. The resulting prototype has been tested by calibrating each sensor used. The results of calibration of the foot pressure sensor with FSR show that there are relatively consistent differences for the FSR1 and FSR2 sensors, but different variations are observed for the FSR3 sensor, ranging from 0.02 kPa to 0.13 kPa. Meanwhile, the temperature sensor calibration between the digital thermometer and thermistor appears to remain relatively constant and is still considered acceptable as a test calibration result, approximately ranging from 0.3°C to 0.4°C. Testing on the lora transmitter and receiver distance connection showed that both test points achieved a 100% success rate in sending data, but there were still lora communication failures that occurred at points 6 and 7, with the success rate falling below 50%. Some of these failures are caused by signal obstacles, such as trees, high ground, buildings, and machine shops, which cause reduced signal absorption from the end node to the gateway. In future research, it is necessary to improve the calibration of the accuracy of each sensor and also rarely communicate data between the transmitter and receiver. Future research could try using several different types of sensors and sensors.

Author Contribution: All authors contributed equally to the main contributor to this paper. All authors read and approved the final paper.

Funding: This research was fully funded by the Ministry of Education and Culture of the Republic of Indonesia through the Beginner Lecturer Research Scheme (PDP) for the 2023 Fiscal Year.

Conflicts of Interest: The authors declare no conflict of interest.

References

[1] A. Nicolucci *et al.*, "Prediction of complications of type 2 Diabetes: A Machine learning approach," *Diabetes Res. Clin. Pract.*, vol. 190, p. 110013, 2022, https://doi.org/10.1016/j.diabres.2022.110013.

[2] N. A. Azit, S. Sahran, V. M. Leow, M. Subramaniam, S. Mokhtar, and A. M. Nawi, "Prediction of hepatocellular carcinoma risk in patients with type-2 diabetes using supervised machine learning classification model," *Heliyon*, vol. 8, no. 10, p. e10772, 2022, https://doi.org/10.1016/j.heliyon.2022.e10772.

[3] S. M. Ganie and M. B. Malik, "An ensemble Machine Learning approach for predicting Type-II diabetes mellitus based on lifestyle indicators," *Healthc. Anal.*, vol. 2, p. 100092, 2022, https://doi.org/10.1016/j.health.2022.100092.

[4] I. D. Federation, *IDF diabetes atlas*. International Diabetes Federation, Executive Office, 2011.

[5] V. Chang, M. A. Ganatra, K. Hall, L. Golightly, and Q. A. Xu, "An assessment of machine learning models and algorithms for early prediction and diagnosis of diabetes using health indicators," *Healthc. Anal.*, vol. 2, p. 100118, 2022, https://doi.org/10.1016/j.health.2022.100118.

[6] H. Permana *et al.*, "Diabetes mellitus patients in Indonesia: management in a tertiary hospital compared to primary health care," *Universa Med.*, vol. 41, no. 2, pp. 157–168, 2022, https://doi.org/10.18051/UnivMed.2022.v41.157-168.

[7] R. Schiel, R. Bambauer, and A. Steveling, "Technology in Diabetes Treatment: Update and Future," *Artif. Organs*, vol. 42, no. 11, pp. 1017–1027, 2018, https://doi.org/10.1111/aor.13296.

[8] O. Alfandi, "An Intelligent IoT Monitoring and Prediction System for Health Critical Conditions," *Mob. Networks Appl.*, vol. 27, no. 3, pp. 1299–1310, 2022, https://doi.org/10.1007/s11036-021-01892-5.

[9] R. Widayanti, E. P. Harahap, N. Lutfiani, F. P. Oganda, and I. S. P. Manik, "The Impact of Blockchain Technology in Higher Education Quality Improvement," *J. Ilm. Tek. Elektro Komput. dan Inform.*, vol. 7, no. 2, pp. 207–216, 2021, https://doi.org/10.26555/jiteki.v7i2.20677.

[10] A. J. Perez, F. Siddiqui, S. Zeadally, and D. Lane, "A review of IoT systems to enable independence for the elderly and disabled individuals," *Internet of Things*, vol. 21, p. 100653, 2023, https://doi.org/10.1016/j.iot.2022.100653.

[11] R. K. J. Charles, A. B. Mary, R. Jenova, and M. A. Majid, "VLSI design of intelligent, Self-monitored and managed, Strip-free, Non-invasive device for Diabetes mellitus patients to improve Glycemic control using IoT," *Procedia Comput. Sci.*, vol. 163, pp. 117–124, 2019, https://doi.org/10.1016/j.procs.2019.12.093.

[12] T. N. Gia *et al.*, "IoT-based continuous glucose monitoring system: A feasibility study," *Procedia Comput. Sci.*, vol. 109, pp. 327–334, 2017, https://doi.org/10.1016/j.procs.2017.05.359.

[13] J. Coates, A. Chipperfield, and G. Clough, "Wearable Multimodal Skin Sensing for the Diabetic Foot," *Electronics*, vol. 5, no. 3. 2016, https://doi.org/10.3390/electronics5030045.

[14] X. Zhang *et al.*, "Custom-Molded Offloading Footwear Effectively Prevents Recurrence and Amputation, and Lowers Mortality Rates in High-Risk Diabetic Foot Patients: A Multicenter, Prospective Observational Study," *Diabetes, Metab. Syndr. Obes. Targets Ther.*, vol. 15, pp. 103–109, 2022, https://doi.org/10.2147/DMSO.S341364.

[15] B. M. Eskofier *et al.*, "An overview of smart shoes in the internet of health things: Gait and mobility assessment in health promotion and disease monitoring," *Appl. Sci.*, vol. 7, no. 10, 2017, https://doi.org/10.3390/app7100986.

[16] R. Rayan, C. Tsagkaris, and I. Romash, "The Internet of Things for Healthcare: Applications, Selected Cases and Challenges," in *IoT in Healthcare and Ambient Assisted Living*, pp. 1–15, 2021, https://doi.org/10.1007/978-981-15-9897-5_1.

[17] D. Farahiyah and B. W. Purnama, "Design Prototype of Temperature and Humidity Control and Monitoring on Weaver Ant Cage based on Internet of Things," *J. Ilm. Tek. Elektro Komput. dan Inform.*, vol. 7, no. 2, pp. 326–337, 2021, https://doi.org/10.26555/jiteki.v7i2.21438.

[18] M. M. Jassem and M. I. Al-nouman, "Design and Implementation of IoT-Based Burglary Detection System," *J. Ilm. Tek. Elektro Komput. dan Inform.*, vol. 9, no. 3, pp. 549–557, 2023,

http://dx.doi.org/10.26555/jiteki.v9i3.26602.

[19] F. D. Rahmaniar, J. Endri, and I. Salamah, “Design of Automatic Organic Fertilizer Processing Tools by Utilizing the Internet of Things (IOT) as a Monitoring System,” *J. Ilm. Tek. Elektro Komput. dan Inform.*, vol. 9, no. 3, pp. 684–692, 2023, http://dx.doi.org/10.26555/jiteki.v9i3.26528.

[20] R. Huchegowda, A. Shruti, S. Amarendra, T. Shraddha, and C. Huchegowda, "Integrative studies to design and validate wearable footwear among neuropathic patients," *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*, vol. 13, no. 3, pp. 2075-2079, 2019, https://doi.org/10.1016/j.dsx.2019.03.038.

[21] N. Kularathne, U. Wijayathilaka, N. Kottawaththa, S. Hewakoralage, and S. Thelijjagoda, “Dia-Shoe: A Smart Diabetic Shoe to Monitor and Prevent Diabetic Foot Ulcers,” in *2019 International Conference on Advancements in Computing (ICAC)*, pp. 410–415, 2019, https://doi.org/10.1109/ICAC49085.2019.9103408.

[22] UNICEF, “Report Analysis On Digital Learning Landscape in Indonesia,” 2021.

[23] D. E. Juliando, R. G. Putra, D. A. Sartika, and R. G. P. Yudha, “Study of Lora Module Ra-02 for Long Range, Low Power, Low Rate Picture Transfer Applications,” *J. Phys. Conf. Ser.*, vol. 1845, no. 1, 2021, https://doi.org/10.1088/1742-6596/1845/1/012054.

[24] M. Monteiro-Soares *et al.*, "Guidelines on the classification of diabetic foot ulcers (IWGDF 2019)," *Diabetes/metabolism research and reviews*, vol. 36, p. e3273, 2020, https://doi.org/10.1002/dmrr.3273.

[25] L. A. Lavery *et al.*, “Home Monitoring of Foot Skin Temperatures to Prevent Ulceration,” *Diabetes Care*, vol. 27, no. 11, pp. 2642–2647, 2004, https://doi.org/10.2337/diacare.27.11.2642.

[26] A. L. de Araújo, F. D. da S. Negreiros, R. S. Florêncio, S. K. P. de Oliveira, A. R. V. da Silva, and T. M. M. Moreira, “Effect of thermometry on the prevention of diabetic foot ulcers: a systematic review with meta-analysis*,” *Rev. Lat. Am. Enfermagem*, vol. 30, 2022, https://doi.org/10.1590/1518-8345.5663.3525.

[27] V. V. Kulkarni and F. Seraj, “An embedded wearable device for monitoring diabetic foot ulcer parameters,” *ACM Int. Conf. Proceeding Ser.*, pp. 345–351, 2020, https://doi.org/10.1145/3389189.3397982.

[28] M. Fierheller and R. G. Sibbald, “A Clinical Investigation into the Relationship between Increased Periwound Skin Temperature and Local Wound Infection in Patients with Chronic Leg Ulcers,” *Adv. Skin Wound Care*, vol. 23, no. 8, 2010, https://doi.org/10.1097/01.ASW.0000383197.28192.98.

[29] K. E. Chatwin, C. A. Abbott, A. J. M. Boulton, F. L. Bowling, and N. D. Reeves, “The role of foot pressure measurement in the prediction and prevention of diabetic foot ulceration—A comprehensive review,” *Diabetes. Metab. Res. Rev.*, vol. 36, no. 4, p. e3258, 2020, https://doi.org/10.1002/dmrr.3258.

[30] W. J. Jeffcoate and K. G. Harding, “Diabetic foot ulcers,” *Lancet*, vol. 361, no. 9368, pp. 1545–1551, 2003, https://doi.org/10.1016/S0140-6736(03)13169-8.

[31] E. Sutkowska, K. Sutkowski, M. Sokołowski, E. Franek, and S. Dragan, “Distribution of the Highest Plantar Pressure Regions in Patients with Diabetes and Its Association with Peripheral Neuropathy, Gender, Age, and BMI: One Centre Study,” *J. Diabetes Res.*, vol. 2019, p. 7395769, 2019, https://doi.org/10.1155/2019/7395769.

[32] S. S. Altayyar, “Bare foot and in-shoe plantar pressure in diabetic males and females – is there difference?,” *Med. Devices Evid. Res.*, vol. 14, pp. 271–276, 2021, https://doi.org/10.2147/MDER.S312739.

[33] E. I. G. Velásquez, V. Gómez, L. Paredes-Madrid, and H. A. Colorado, “Error compensation in force sensing resistors,” *Sens. Bio-Sensing Res.*, vol. 26, p. 100300, 2019, https://doi.org/10.1016/j.sbsr.2019.100300.

[34] K. Ulya, I. Yahya, C. Arif, L. Pradigta, and S. Raharja, “Monitoring and Control Design of Automatic Transfer Switch- Automatic Main Failure with Human Machine Interface (HMI),” *J. Ilm. Tek. Elektro Komput. dan Inform.*, vol. 8, no. 3, pp. 475–485, 2023, https://doi.org/10.26555/jiteki.v8i3.23750.

[35] R. Rahmatullah, T. M. Kadarina, B. B. Irawan, R. Septiawan, and A. Rufiyanto, “Design and Implementation of IoT-Based Monitoring Battery and Solar Panel Temperature in Hydroponic System,”

J. Ilm. Tek. Elektro Komput. dan Inform., vol. 9, no. 3, pp. 810–820, 2023, http://dx.doi.org/10.26555/jiteki.v9i3.26729.

[36] B. Paul, "An Overview of LoRaWAN," *WSEAS Trans. Commun.*, vol. 19, pp. 231–239, 2021, https://doi.org/10.37394/23204.2020.19.27.

[37] Y. Apriani, W. A. Oktaviani, and I. M. Sofian, "Vessel Tracking System Based LoRa SX1278," *J. Ilm. Tek. Elektro Komput. dan Inform.*, vol. 9, no. 3, pp. 693–707, 2023, http://dx.doi.org/10.26555/jiteki.v9i3.26385.

[38] J. M. Paredes-Parra, A. J. García-Sánchez, A. Mateo-Aroca, and Á. Molina-García, "An alternative internet-of-things solution based on LOra for PV power plants: Data monitoring and management," *Energies*, vol. 12, no. 5, 2019, https://doi.org/10.3390/en12050881.

[39] P. D. P. Adi, A. Kitagawa, D. A. Prasetya, R. Arifuddin, and S. Yoseph, "LoRaWAN Technology in Irrigation Channels in Batu Indonesia," *J. Ilm. Tek. Elektro Komput. dan Inform.*, vol. 7, no. 3, p. 522, 2022, https://doi.org/10.26555/jiteki.v7i3.22258.

[40] E. Guney, G. Agirtas, and C. Bayilmis, "MongoDB Based Real-Time Monitoring Heart Rate Using Websocket For Remote Healthcare," *J. Ilm. Tek. Elektro Komput. dan Inform.*, vol. 8, no. 4, pp. 500–508, 2022, https://doi.org/10.26555/jiteki.v8i4.25052.

[41] M. F. Wicaksono, M. D. Rahmatya, U. K. Indonesia, J. Dipati, and U. No, "IoT for Residential Monitoring Using ESP8266 and ESP-NOW Protocol," *J. Ilm. Tek. Elektro Komput. dan Inform.*, vol. 8, no. 1, pp. 93–106, 2022, https://doi.org/10.26555/jiteki.v8i1.23616.

[42] D. A. Aziz, "Webserver Based Smart Monitoring System Using ESP8266 Node MCU Module," *Int. J. Sci. Eng. Res.*, vol. 9, no. 6, pp. 801-807, 2018, https://www.ijser.org/onlineResearchPaperViewer.aspx?Webserver-Based-Smart-Monitoring-System-Using-ESP8266-Node-MCU-Module.pdf.

[43] A. Perrier *et al.*, "Smart Diabetic Socks: Embedded device for diabetic foot prevention," *IRBM*, vol. 35, 2014, https://doi.org/10.1016/j.irbm.2014.02.004.