Smart Posture System Design for Scoliosis Patients Based on the Internet of Things (IoT)

Anhar
Electrical Engineering Department
University of Riau
Pekanbaru, Indonesia
anhar@lecture.unri.ac.id

Salpiana
Electrical Engineering Department
University of Riau
Pekanbaru, Indonesia
Salpiana0632@student.unri.ac.id

Siva Kumar Subramaniam
Faculty of Electronics and Computer Eng.
Universiti Teknikal Malaysia Melaka
Melaka, Malaysia
Siva@utem.edu.my

Indra Yasri
Electrical Engineering Department
University of Riau
Pekanbaru, Indonesia
Indra.yasri@lecturer.unri.ac.id

Febrizal Ujang
Electrical Engineering Department
University of Riau
Pekanbaru, Indonesia
febrizal@lecturer.unri.ac.id

Ery Safrianti
Electrical Engineering Department
University of Riau
Pekanbaru, Indonesia
erysafrianti@lecturer.unri.ac.id

2024 4th International Conference on Electrical Engineering and Informatics (ICon EEI) | 979-8-3315-4079-1/24/$31.00 ©2024 IEEE | DOI: 10.1109/IConEEI64414.2024.10747938

Abstract— ***Scoliosis, a spine deformity characterized by an abnormal curvature, often in the shape of the letter C or S, is a condition with an unknown cause in most cases (75-85% are idiopathic scoliosis). In this context, our research is a comprehensive exploration, aiming to design an intelligent body posture system for people with scoliosis using Internet of Things (IoT) technology. The system employs a flex sensor to measure the angle of spinal curvature and ESP 32 as a processor and controller server. The research yields hardware and software angles and conditions. There are three scenarios to test the performance of the system; testing on normal patients without complaint, with complaint, and scoliosis patients. Voltage measurements show error values ranging from 0,87%-17,7%, and the tool functions effectively. The device testing is conducted on both regular patients and scoliosis sufferers for monitoring and early detection.***

Keywords: Internet of Things (IoT), scoliosis, Blynk application, flex sensor, ESP 32.

I. Introduction

Scoliosis is when the spine curves laterally more than 10 degrees, often accompanied by spinal rotation. It usually occurs in children before they enter puberty, particularly between the ages of 10 and 15, and affects about 2% to 4% of the adolescent population[1]. One way to identify scoliosis is by continuously monitoring body posture. However, manual observation of a person's posture is often impractical and inaccurate. The only way to definitively determine if someone has scoliosis is through X-rays, CT scans, or MRI examinations. However, the use of X-rays can negatively impact the human body, such as skin discoloration and bone weakening, and it can even cause conditions like aplastic anemia, where the production of new blood cells in the body stops. Scoliosis can be classified as congenital and neuromuscular (idiopathic) disorders based on the etiology.

Congenital disorders refer to structural or functional abnormalities that arise due to disruptions occurring during the intrauterine period or human development in the womb, from the creation of the egg cell by sperm to the birth of the baby.[2]. Neuromuscular disorders can be diagnosed by observing clinical symptoms and conducting careful neurological examinations. Anatomically, disorders of the peripheral nervous system start from the anterior horn of the spinal cord and extend to the neuromuscular junction[3].

In an increasingly advanced technological era, the Internet of Things (IoT) has emerged as an up-and-coming solution for error monitoring. Therefore, IoT-based solutions have become a recognized approach for monitoring and early detection of body posture. IoT devices enable connectivity with other devices to collect real-time data and communicate over the internet. Hence, the development of IoT-based body posture detection and early warning systems is crucial[4].

Previous research has conducted IoT-based body posture detection systems. This system monitors body condition using an Android application and several sensors, like Node MCU, which initialized the system. Another research study focuses on correcting sitting positions by analyzing body posture using pressure sensors. No research has proposed a posture design to monitor scoliosis patients.

Therefore, this research represents a significant departure from previous studies. It adds a scoliosis prevention and rehabilitation system for individuals suffering from scoliosis and lower back pain. Additionally, the study includes alert functions that notify if the body position is incorrect, which can trigger scoliosis and lower back pain if maintained for prolonged periods. Analysis of human posture has numerous applications in sports and medical science. Hence, the Internet of Things foundation can be used to recognize and detect human body posture. The body posture detection system is designed to use flex sensors to measure flexibility levels, a vibration motor to generate mechanical vibrations, and an ESP32 to receive input signals from the sensors. The data is then compared with previously stored ideal posture data.

II. Related Works

This research aims to develop a combined approach to create an appropriate healthcare system that is beneficial for both patients and medical professionals. The main focus of this research is on low cost, compact design, ease of understanding, and portability, making it usable anywhere. Many existing healthcare monitoring systems have drawbacks such as low power efficiency, large device size, low response, and others. This wearable wireless system can help overcome these weaknesses. Below are some significant and related works discussed in the literature.

In [4] the author developed an IoT-based body posture detection system aimed at addressing long-term issues with suboptimal body posture. The system utilizes an IMU MPU 9250 to measure spinal movements, a Bluetooth module HC-05 for wireless data transmission, a piezo buzzer for alerting poor back posture, and three LED lights for visual posture indication.

In [5] author highlights the use of sensor technology in IoT-based body posture detection. Two main approaches are considered invasive, with sensors placed inside or on the body surface, and non-invasive, using cameras and computer vision. The non-invasive method focuses on posture detection through pressure distribution measurements or sensors such as pressure, ultrasonic, accelerometer, and gyroscope. The Arduino platform is utilized for system implementation, with sensor outputs fed into a K-nearest neighbor (KKN) machine learning algorithm. The study reports a high precision of ±0,1° for all range of motion (ROM) angles.

In [6] the author proposes a real-time body posture monitoring system using an accelerometer sensor connected to the Blynk application via IoT. Utilizing Arduino as the microcontroller and various other sensors, the system provides immediate feedback on the quality of body posture with messages such as "not in position" and "posture worse." And "posture not ok." The collected data can be accessed by doctors to monitor and correct body posture via Wi-Fi. Additionally, the research yields a portable wearable device to enhance the efficiency of body posture monitoring.

In [7] the author proposes a design for an IoT-based smart posture detection system integrated into wearable clothing. This system would feature notifications and vibrations when body posture is poor, utilizing IMU and flex sensors for active monitoring.

In [8] The author discusses the development of an alert system to monitor body posture, eye distance, and working duration in front of a computer using sensors such as VL53LOX and MPU 6050. The research findings demonstrate the system's effectiveness in providing auditory alerts when eye distance is less than 40 cm or when body posture inclines more than 80° and reminding users to take breaks after 20 minutes of computer use.

In [9], the author proposes developing a body posture alarm prototype based on Node MCU ESP8266 with a flexible spine curvature sensor. The prototype would be installed on a shoulder brace to correct improper sitting posture and prevent bone disorders. The research findings highlight the influence of age and weight on changes in spine curvature.

TABLE. I. COBB ANGLE STANDARDS

No	Cobb angle	Definition
1.	0°- 10°	Spinal curve
2.	10°- 20°	Mild scoliosis
3.	20°- 40°	Moderate scoliosis
4.	>40°	Severe scoliosis

In [10] the author proposes an automated system to measure spinal curvature from anterior-posterior (AP) view X-ray images. This system employs deep learning approaches with convolutional neural networks (CNN) such as U-Net, Dense U-Net, and Residual U-Net for vertebra segmentation. The segmentation results are then used to calculate the Cobb angle. Experiments show that Residual U-Net provides the best results, with measurements not significantly different from manual measurements by specialists. Table 1 represents the standard angles used to determine the severity levels in scoliosis patients.

III. System Description

A. System Structure

The body posture detection network architecture design involves interconnecting devices for data transmission, as shown in Fig. 1. The system includes ESP32, a flex sensor, a vibration motor, and an LED to monitor and detect body posture issues early. The internet network enables remote control and monitoring of hardware, while Blynk serves as the user interface (GUI), providing visual elements to display spinal curvature measurements.

This system is divided into two different sides, namely the web application side with web pages and databases used and the patient side with sensors used for scoliosis detection. Fig. 2 illustrates the flow chart of the system, and Fig. 3 illustrates the sensor circuit diagram used by the patient.

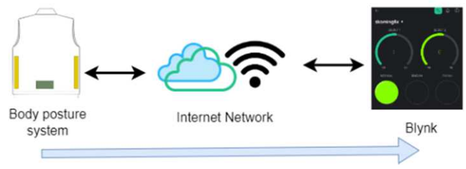

Fig. 1. Body posture detection network architecture

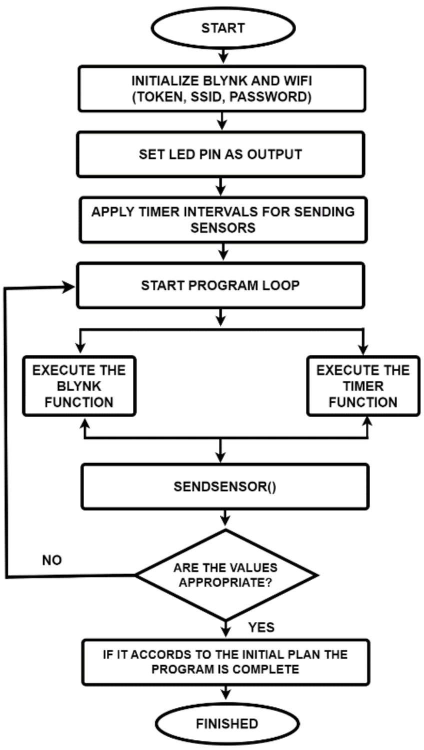

Fig. 2. Flow chart of the system

.

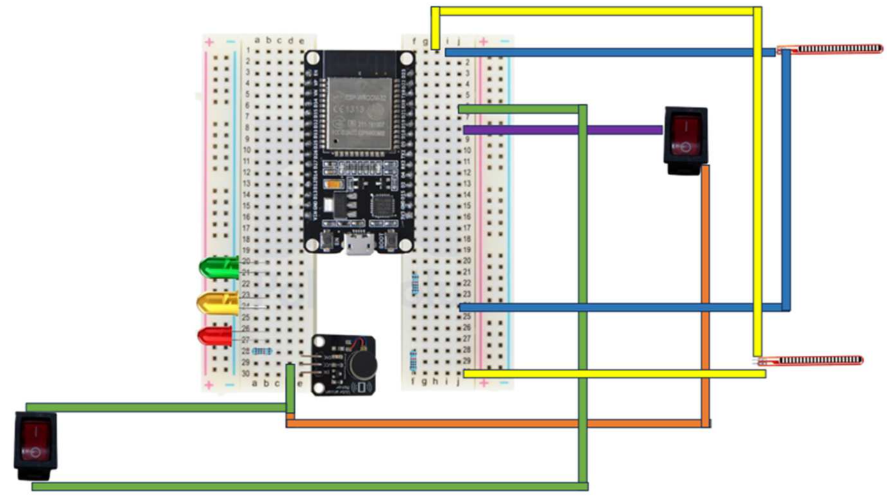

Fig. 3. Circuit simulation of the system.

B. *Blynk app*

Blynk is an Internet of Things platform that allows users to control hardware, display sensors, store data, describe it, and perform various other functions[11]. There are three important parts of Blynk namely:

The Blynk application allows users to create an interface according to their wishes using the widgets provided.

The Blynk server is responsible for all communications between the smartphone and the hardware.

Blynk Libraries allow hardware to connect to the server and process incoming and outgoing commands

This application is very easy for laypeople to use. No special skills are required to run the Blynk application. Apart from that, the Blynk application has many features that make it easier for users to use simply by dragging and dropping. Blynk is not limited to any particular module. This application can be used as a remote controller or monitor as long as it is connected to the internet[12].

Blynk is an IoT application designed to make creating control systems and sensor readings from ESP32 and Arduino modules easier and faster. Apart from functioning as an "IoT cloud", Blynk is also an end-to-end solution for building useful applications for connected products and services [13].

C. *Wearable Device*

The microcontroller used in this device is ESP32. Here, we employ one sensor, namely the flex sensor, to measure the flexibility of body posture in degrees. The flex sensor continuously sends data to the ESP32 as long as the device is in use by the patient. The ESP32 retrieves data from the sensor and transmits it to the Blynk server. In severe posture conditions, the vibration motor signals the patient with vibrations, accompanied by alerts from the Blynk application. In moderate and normal conditions, an LED lights up yellow for moderate and green for normal posture. Fig. 3 provides an overview of the device's development.

IV. Equipment Details

A. Hardware Module Description

In this paper, different instruments and technologies have been used to achieve better output within the desired architecture. Sensors and modules are discussed below:

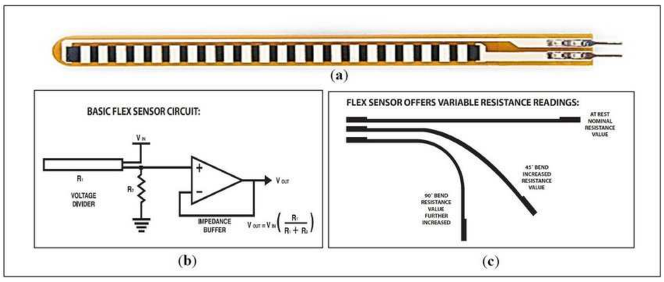

Fig. 4. (a) Flex sensor (b) Basic circuit for flex sensor (c) Reading variable resistance on flex sensor.

a) Node MCU ESP32

The ESP32 is a microcontroller developed by Espressif Systems, featuring integrated Wi-Fi and Bluetooth modules, designed for low power consumption and high radio frequency performance, making it ideal for reliable and energy-efficient IoT applications[14]. The ESP32 Devkitc V4 is a versatile development board featuring the ESP32 chip, equipped with a dual-core Xtensa 32-bit CPU and integrated Wi-Fi, Bluetooth, and BLE modules, making it ideal for IoT application development with compatibility for Arduino IDE, PlatformIO, and ESP-IDF SDK.

The reasons for choosing ESP32 in this research include its integration with Wi-Fi modules, eliminating the need for additional modules, and its dual-core architecture, which allows it to run two programs simultaneously.

b) Flex sensor

A flex sensor is a type of sensor that changes resistance when it bends, thus detecting curvature. It operates on a principle similar to a variable resistor, providing resistance to the microcontroller after being supplied with the same voltage[15].

Fig. 4 concludes that as the flex sensor bends more, its resistance value increases. Therefore, a voltage divider circuit configuration can be used to calculate the resistance value of the flex sensor.

c) LED (Light Emitting Diode)

LED, short for Light-Emitting Diode, is a semiconductor that emits light when an electric current passes through it. It is commonly used as an indicator light in electronics. LED can achieve speeds up to 50 Mb/s without needing an optical stabilizer in data transmission over multimode optical fibers. It emits light with low temporal and spatial coherence and a narrow frequency spectrum.

d) Vibration Motor

Vibration motors are specialized motors designed to generate mechanical vibrations. They are typically small and lightweight and are used in various applications, including mobile phones, haptic devices, toys, and other electronics. They typically use centrifugal or eccentric forces to produce rotational motion converted into linear vibrations, which are commonly employed for haptic feedback in electronic devices such as vibration notifications on phones or tactile effects in gaming.

e) Power Bank

A power bank is a technology that charges smartphones flexibly anywhere, functioning as a portable energy storage or backup battery[16]. The power output varies depending on the specifications, typically with a standard output voltage of around 5V. However, power conversion efficiency and bank limitations result in sustained low maximum output currents. If the output voltage does not match the device's requirements, issues such as slow charging or failure to charge (under voltage) may occur. Conversely, if the voltage is too high (over voltage), it can potentially damage electronic components, triggering over-voltage protection or causing permanent device damage.

V. Results And Discussion

In the results and discussion, we will explain the findings of testing the scoliosis disturbance detection device prototype. Here are some further results and discussions regarding the assembled device and its testing.

A. Results and Discussion of Hardware Design

The hardware design resulted in a prototype. Fig. 5 displays the devices that can be worn by patients, such as when wearing clothes.

Fig. 6 shows the display when the prototype is used by the patient. Here is an explanation of the numbering provided:

1. A waist belt featuring flex sensors to measure body inclination/curvature.
2. Adjustment strap designed to control the height of the object.
3. The microcontroller box serves as a housing for components such as LEDs, vibration motors, and ESP32.

Fig. 5. The design of the prototype

.

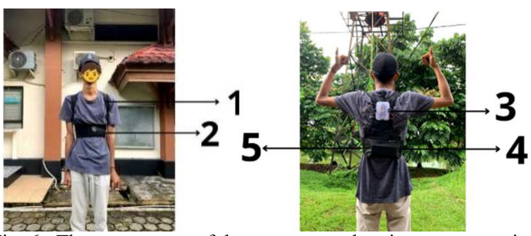

Fig. 6. The appearance of the prototype when in use on a patient

4. Power bank compartment
5. Location of flexible sensors

B. Results and discussion of prototype voltage measurements

Table II shows the prototype's voltage measurement results. The error value is below 20%, and the tool works well as expected. However, Undervoltage still occurs on several devices, but it doesn't affect the tool's performance. It is still within the tool's performance tolerance limits.

TABLE. II. The results of the measurement and the calculation of voltage error values.

No	Device	Dataset Output Voltage (V)	Output voltage Measurement Results (V)	*Error* (%)
1.	Adapter	5	5.060	1.2
2.	*Power bank*	5	4.958	0.84
3.	The GND and Vin output pins are used by the flex sensor on the ESP 32	5	4.371	12.58
4.	Flex sensor voltage	5	4.381	12.38
5.	LED voltage	5	4.145	17.7
6.	Motor vibration voltage	5	4.314	13.72

C. Results and discussion of Blynk software design

Fig. 7 shows the GUI designed for the Blynk IoT Android application for monitoring the scoliosis disturbance. The following is an explanation of the parts that have been numbered.

1. Project name
2. Settings
3. Notifications
4. Application help center
5. Views for scoliosis angle
6. LED to display the severity of scoliosis
7. Real-time spine movement graph

Fig. 7. GUI on the designed system application

D. Results and discussion of the level of success of the tool

In the discussion in this subchapter, testing is explained to measure the success of the tool. Several scenarios can be carried out in the test, namely:

1. Testing with normal patients without complaints
   Testing is carried out on patients who have never had their bones checked by a doctor. In his medical history,

there has never been a complaint about the spine. Table III represents the results of the test.

TABLE. III. TESTING ON NORMAL PATIENTS WITHOUT COMPLAINTS

No	LED on the device	LED on Blynk	D1	D2	Information
1.			10	4	Normal
2.			38	28	Light
3.			67	58	Critical

Of the three positions that were tested on the first patient, who had never had a spinal examination and had never complained about his spine and whose body was in an upright condition without making any movements when using tools, it was stated that his condition was normal. However, when the patient makes movements that could harm the patient's spine, the device will provide an early warning in the form of a change in the LED color from normal to mild and mild to severe.

2. Testing patients with complaints
   The second patient's testing was carried out by the same person as the first patient's; that is, they had never been examined by a doctor. It's just that he often complains of back pain when lifting heavy loads on his back.

TABLE. IV. TESTING OF NORMAL PATIENTS WITH COMPLAINTS

No	LED on the device	LED on Blynk	D1	D2	Information
1.			31	39	Light
2.			39	39	Light
3.			48	53	Critical

Three positions are shown in tests with patients who have never had a spinal examination, as shown in Table IV. However, people often complain about their spines when doing heavy activities. If the patient is already in a condition of mild scoliosis when carrying out the test in an upright position, he cannot return to his normal condition, but the condition can escalate to become severe.

3. Testing with scoliosis patients
   Testing is carried out on patients who have scoliosis and have been examined by a doctor.

Fig. 8. Patient x-ray results

Before the device is tested on a scoliosis patient, the patient first undergoes an X-ray to determine the degree and severity of the scoliosis and validate whether the device matches the doctor's examination results. Fig. 8 shows that the patient had a scoliosis issue based on the X-ray results

TABLE. V. TESTING OF SCOLIOSIS PATIENTS

No	LED on the device	LED on Blynk	D1	D2	Information
1.			36	43	Light
2.			38	47	Light
3.			42	48	Critical

The test results from several test conditions showed that the scoliosis was 45 degrees on the doctor's examination. However, when testing was carried out using a screening tool, the test results were found to be different but still within the 45-degree range. From the X-ray results shown in Fig. 14, it can be seen that the patient's spine is S-shaped.

VI. CONCLUSION

Based on the research and testing conducted, the prototype device, consisting of hardware (flex sensor, ESP

32 microcontroller, LED, vibration motor, and power bank) and software using the Blynk application, was successfully developed and can be worn like a regular shirt. Despite voltage error values ranging from 0.84% to 17.7%, the device functions well. Testing showed that the device can detect Cobb angles and provide appropriate notifications, working consistently on normal patients, patients with complaints, and scoliosis patients. The device is effective in providing early warnings through LED changes and motor vibrations, aiding in the monitoring and early detection of scoliosis.

References

[1] Mentri Kesehatan Republik Indonesia, *Keputusan Mentri Kesehatan Republik Indonesia Nomor HK.01.07/MENKES/6542/2021 tentang Pedoman Nasional Pelayanan Kedokteran Tata Laksana Skoliosis Idiopatik Remaja*. 2021.

[2] Z. Maritska and S. R. Anissya Kinanti, "Kejadian dan Distribusi Kelainan Kongenital Pada Bayi Baru Lahir di RS dr. Moehammad Hoesin Palembang Periode Januari-November 2015," *JK Unila* |, vol. 1, p. 347, 2016, [Online]. Available: http://www.who.int/mediacentre/factsh

[3] M. Milanti Dewi, D. Putro Widodo, R. Amardiyanto, N. Sinaga, and N. Hidayah, "Prevalensi, Spektrum Klinis dan Gambaran Neurofisiologi Kasus Neuromuskular," *Sari Pediatri*, vol. 20, no. 4, 2018.

[4] G. Karanth, N. Pentapati, S. Gupta, and R. Ravish, "IoT Based Smart Posture Detector," in *Proceedings of the Global AI Congress*, Springer, 2019, pp. 197–206. doi: 10.1007/978-981-15-2188-1_16.

[5] J. Gupta, N. Gupta, M. Kumar, and R. Duggal, "An Introduction to IoT Based Posture Detection and Underlying Sensor Technology."

[6] B. Vidhya, A. A. Hayum, G. Saranya, M. Aarthi, V. Aishwarya, and K. Dhanashree, "Smart Posture Detector Using IOT," in *Proceedings of the 6th International Conference on Communication and Electronics Systems, ICCES 2021*, Institute of Electrical and Electronics Engineers Inc., Jul. 2021, pp. 713–718. doi: 10.1109/ICCES51350.2021.9489099.

[7] S. Dhulap, A. Patil, S. Kamble, S. Apana, and G. P. Mhatre, "IOT Based Smart Wearable Posture Detection & Alert System," *International Journal of Engineering Research and Applications www.ijera.com*, vol. 11, pp. 55–60, 2021, doi: 10.9790/9622-1107065560.

[8] M. Anggraini and W. Wildian, "Rancang Bangun Sistem Peringatan Posisi Tubuh, Jarak Pandang, dan Durasi Kerja Di Depan Komputer," *Jurnal Fisika Unand*, vol. 12, no. 1, pp. 49–55, Dec. 2022, doi: 10.25077/jfu.12.1.49-55.2023.

[9] C. D. Setyawan and A. Wicaksono, "Body Posture Position Alarm Prototype Based on NodeMCU ESP8266," *Buletin Ilmiah Sarjana Teknik Elektro*, vol. 5, no. 4, pp. 614–622, 2023.

[10] M. H. Horng, C. P. Kuok, M. J. Fu, C. J. Lin, and Y. N. Sun, "Cobb angle measurement of spine from x-ray images using convolutional neural network," *Comput Math Methods Med*, vol. 2019, 2019, doi: 10.1155/2019/6357171.

[11] F. Mushoffa, "Pemantauan Sinyal Vital Untuk Identifikasi Kondisi Tubuh Pasien Menggunakan Sistem Telemedika Berbasi IoT," Skripsi, Universitas Islam Negeri Walisongo, Semarang, 2021.

[12] M. Artiyasa *et al.*, "Aplikasi Smart Home Node MCU IoT untuk Blynk," *Jurnal Rekayasa Teknologi Nusa Putra*, vol. 7, no. 1, pp. 1–7, 2020.

[13] O. Hendri and T. Dwika, "Sistem Kendali dan Monitoring menggunakan Aplikasi Blynk dan Mikrokontroler wermos D1 R2 berbasis Internet of Things pada Pembuatan Tempe," Skripsi, Universitas Lampung, Lampung, 2022.

[14] T. M. Raihan, F. Sains, and D. Teknologi, "Sistem pemantauan kualitas air menggunakan Esp32 dengan Fuzzy Logic Sugeno Berbasis Android," Skripsi, Universitas Islam Negeri Syarif Hidayatullah, Jakarta, 2022.

[15] A. Tiara Nirwani, "Simulator Kursi Roda Otomatis Dengan Sensor Flex Berbasis Mikrokontroler," Tugas Akhir, Universitas Negeri Yogyakarta, Yogyakarta, 2018.

[16] T. K. Aminardi and A. Z. Falani, "Sistem Pendukung Keputusan untuk Pemilihan Powerbank Sesuai Budget Menggunakan Metode Simple Additive Weighting (SAW)," *Jurnal Ilmiah : Lintas Sistem Informasi dan Komputer (LINK)*, vol. 26, no. 2, 2017.