Leakage Warning System and Monitoring Lapindo Sidoarjo Mud Embankment Based on Internet of Things

[1]Shon Haji, [2]Akhmad Ahfas, [3]Syamsudduha Syahrorini, [4]Shazana Dhiya Ayuni
[1,2,3,4]Department of Electrical Engineering, Faculty of Science and Technology, Muhammadiyah University of Sidoarjo
Email: [1]shonhaji247@gmai.com, [2]ahfas@umsida.ac.id, [3]syahrorini@umsida.ac.id, [4]shazana@umsida.ac.id

Article Info

Article history:
Received Aug 28th, 2023
Revised Nov 26th, 2023
Accepted Dec 17th, 2023

Keyword:
Embankment Mud
ESP32-Cam
Mitigation System
MPU-6050 Sensor
SW-420 Sensor

ABSTRACT

The emergence of the Lapindo Sidoarjo mudflow has a long history since 29 May 2006. The point of the mudflow is in Siring Village, and until now, it has shown no signs of stopping. Sidoarjo residents are still fearful of the impact and recurrence of the mudflow, especially those still living around the embankment. The real impact is often still felt, such as embankment leaks, embankment collapses, or overflowing water mixed with mud during high rainfall, making people who still live around the embankment anxious. The unavailability of monitoring information to the public and the unclear mitigation system makes it necessary to have an information system that is easily accessible to the public. Therefore, by utilizing the advances in Internet of Things technology, this research will design a prototype system to monitor the conditions around Lapindo Sidoarjo Mud using Telegram Bot as a user interface, the ESP32-Cam microcontroller board, SW-420 vibration sensor, and MPU-6050 accelerometer sensor. The result of testing this prototype tool is that the Telegram user will receive a notification if the condition of the prototype field is experiencing vibrations or changes in position. Other than that, the Telegram user can also request real-time information, such as temperature, the axis position of the prototype as an initial benchmark, and the current photo to know the condition of the Lapindo Sidoarjo mud embankment. That way, it is hoped that this prototype system will become a monitoring and mitigation solution for the local people and the general public who reach this Telegram Bot room chat.

Corresponding Author:
Akhmad Ahfas,
Department of Electrical Engineering, Faculty of Science and Technology
Muhammadiyah University of Sidoarjo,
Raya Gelam Street, No.250, Candi, Sidoarjo 61271, East Java, Indonesia.
Email: ahfas@umsida.ac.id

DOI: http://dx.doi.org/10.24014/ijaidm.v7i1.25269

1. INTRODUCTION

The Lapindo Sidoarjo mudflow has a long history since 29 May 2006. The disaster affected three sub-districts in Sidoarjo with mud inundation. The point of the mudflow is in Siring Village, Porong, Sidoarjo, and until now, it has shown no signs of stopping. One of the measures taken is the construction and strengthening of the mud embankment infrastructure. The latest data cited from the PPLS electronic book (2020), the length of the mud embankment reached 22,088 meters, and the length of the gabions reached 12,312 meters [1]. Handling of the Lapindo Sidoarjo Mudflow must face several challenges, one of which is the impact of the embankment infrastructure with an elevation of 9-12 meters above sea level built on soft soil foundations and unstable conditions so that it requires regular checking or monitoring of the embankment building while continuously strengthening the infrastructure.

Sidoarjo residents are still fearful of the impact and recurrence of the mudflow, especially those still living around the embankment. Although an institution called the Sidoarjo Mud Control Centre (PPLS) keeps monitoring the mud area and has determined a safe radius for living, it wasn't enough to clear residents' fears about the safety of the embankment. The real impact is often still felt, such as embankment leaks, embankment collapses at some point, or overflowing water mixed with mud during high rainfall, making people who still live around the embankment anxious [2].

Until now, PPLS has no concrete mitigation scheme, and residents don't have a monitoring information system. So, if the residents' fears happen, it will take a long time to handle because they are not aware of the safety condition of the Lapindo mud embankment. In an era with technology growing as fast as today, humans develop technology from the vital side of a problem they face, so technology is essential to facilitate all sectors of human activity [3]. Nowadays, humans can also access information easily without restrictions on space and time. The development of smartphones is increasing in the use of applications with the support of the Android system, and humans continue to develop features such as equipment automation or operating other systems remotely [4].

The Internet of Things (IoT) means an extension of network connectivity and computing capabilities to objects, devices, sensors, and items not usually considered computers [5]. This "smart object" requires little human interaction to generate, exchange, and consume data. They often feature connectivity to remote data collection, analysis, and management capabilities [6]. One of the closest and easily accessible forms of the Internet of Things for smartphone users is the Telegram Bot, which is one of the features of the Telegram instant messaging application that allows users to create, manage, and process messages and provide responses according to the desire of the user [7].

As a literature review, research conducted by Shazana Dhiya Ayuni, Jamaaluddin, and Sy. Syahrorini (2021) named "MMA7361 Accelerometer Sensor as Vibration Detection on Lapindo Mud Embankment". This research monitors embankment vibration using the Blynk application as a user interface, with the integration of the MMA7361 sensor as a tilt detector, Arduino Uno Rev3 as a microcontroller, and ESP8266 as a Wi-Fi module. Every vibration will show in real-time at Blynk. When an accident happens, the application will send a warning and notification to smartphones so they can save their lives and property [8]. Another research is entitled "The Use of Sensor Networks to Monitor Cracks in Buildings Based on the Internet of Things". This research monitors building cracks with the concept of the Internet of Things (IoT) using two Vibration Sensor devices connected to Arduino as a controller for the ignition of the vibration level notification LED and to NodeMCU as a sender of vibration value or level information to the computer (ThingSpeak) in real-time [9]. Then research is entitled "Forest Fire Early Warning System Using NodeMCU Module and Telegram Bot with the Concept of Internet of Things (IoT)". This research develops a forest fire early warning system using the nodeMCU module, temperature sensor, smoke sensor, and Telegram BOT with the concept of the Internet Of Things (IoT) [10]. And last, research entitled "Earthquake Location Detection System Using Arduino Mega 2560, SW-420 Sensor, GPS, and SMS Notification". This research designs an earthquake location detection system using Arduino Mega, vibration sensors as triggers, and GPS as earthquake locators, then sends SMS notifications to users [11].

The novelty offered for this research is the use of a telegram bot as a user interface that is more efficient and easier for the general public, as well as the combination of accelerometer sensors, vibration sensors, and cameras, all of which can provide real-time readings so that this system can answer the purpose of this research, which is to create a monitoring and mitigation system that is better and closer to the public.

2. RESEARCH METHOD

The method used in this research is building and testing a prototype system. The first step is to study the existing literature, survey the location, and calibrate or determine the adjustment variables for the sensors. After that, it continued by preparing tools and materials for designing the system, making program coding, interfacing the system, making prototypes, testing the system, and analyzing the test results.

2.1. Block Diagram of The Components

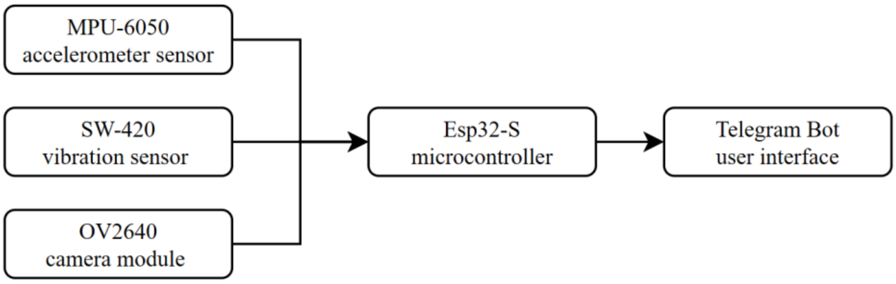

Figure 1. Block diagram of the components system

During the design process, their classification of components in the block diagram as input, process, and output. In the input section, there are three components which are the MPU-6050 accelerometer sensor to detect if there is any movement of the ground on the embankment, the SW-420 vibration sensor to detect vibration, and the OV2640 camera module (built into the AI-Thinking ESP32-Cam Board) to capture photos of the current condition of the embankment. In the process section, there is an ESP32-Cam which uses the Esp32-S microcontroller chip as the primary controller for this system. In the output section, there is a Telegram Bot on a smartphone as a user interface that can receive and query the information provided from the read-out of components. The explanation of the design process also can be seen in Figure 1.

The MPU 6050 is a type of sensor with a 3-axis Accelerometer and 3-axis Gyroscope and already has Digital Motion Processors [12], this sensor can also be used to measure vibrations that occur in vehicles, buildings, machines, and others [13]. The SW-420 sensor is one of the seismic transducers, which is a sensor used to measure velocity and acceleration. To measure speed, it uses a velocity probe and velomitor probe. While to measure acceleration, it uses an acceleration probe sensor [14]. OV2640 is a type of small camera, that is usually used in microcontroller projects and this module is embedded in the ESP32-Cam Board [15].

The ESP32-S is the microcontroller used by the ESP32-Cam Board, which is an electronic board or module with an AI-Thingker concept (artificial intelligence), that functions as a programming tool and can connect to Wi-Fi and the Internet of Things system [16], an example of an ESP32-Cam project is such as the Design of an Automatic Weed-Cutting Robot Using Wireless Controller Module Esp32-Cam Based On Internet Of Things (IoT) [17], Development Of Monitoring Tower Using Gyroscope Sensor Based On Esp32 Microcontroller [18], In the output section there is a telegram bot, which is a robot programmed with various commands to carry out the instructions given by the user [19]. This bot is only a Telegram account operated by software that has AI (Artificial Intelligence) features [20].

2.2. Flowchart Program

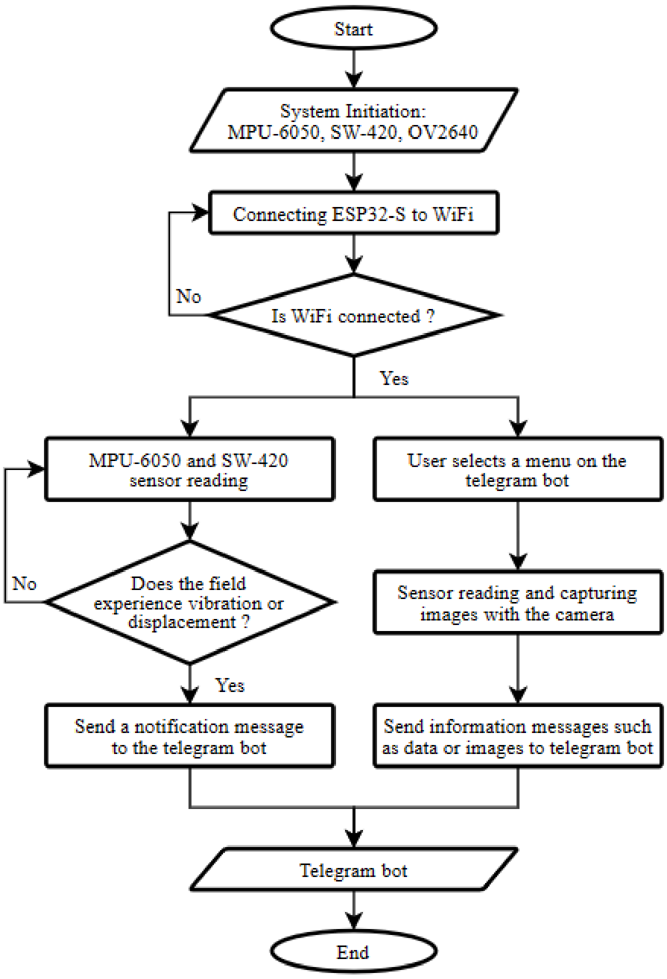

Figure 2. Systematic program flowchart

As an illustration of the system processes, Figure 2 shows a systematic program flowchart. The program starts when the whole circuit is connected to the voltage source, and then the Esp32-S microcontroller will automatically try to connect to the WiFi network whose ID and password have been written in the program code. After connecting to WiFi, the program is ready to work either passively or actively. In the first flow (passively), the program will wait for vibrations or field coordinate movement to send notification messages to the Telegram Bot. The other flow (actively) Telegram users can request information on the menu such as temperature, the axis position of the prototype as an initial benchmark, and the current photo to know the condition of the Lapindo Sidoarjo mud embankment, then the system will process and send the results (data or picture) to the Telegram Bot.

2.3. Assembly The Component

In the component assembly process, the thing to note is that the input/output port interface connection must be suitable so that the system can run properly, not only according to the function of the I/O port but also according to the addressing that has been written in the program code. As seen from the wiring diagram figure below, the ESP-32 Cam that has a built-in ESP32-S microcontroller and OV2640 camera module have a total of 16 pins with 9 general-purpose input output pins (GPIO), 5V and GND pins are connected to the power supply which is also connected to the VCC and GND pins of the SW-420 sensor, GPIO 12 pin to the D0 pin of the SW-420 sensor, GPIO 15 pin to the SCL pin and GPIO 14 pin to the SDA pin of the MPU-6050 sensor, while the VCC and GND pins of the MPU-6050 sensor are taken from the 3V3 and GND pins of the ESP32-Cam. More specific details will be written on the ESP32-Cam port usage table.

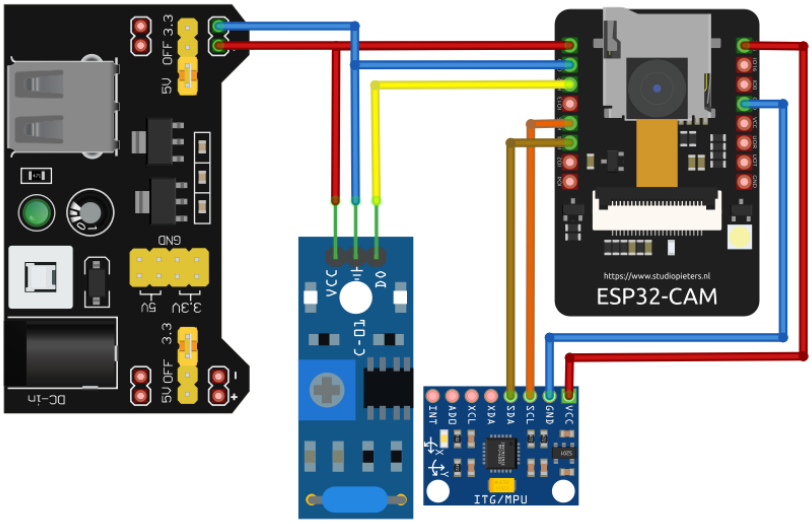

Figure 3. Wiring Diagram

Table 1. ESP32-Cam port usage

No	ESP32-Cam Port	Usage
1.	5V	5V (Power Supply)
2.	GND	GND (Power Supply)
3.	3V3	VCC (MPU-6050)
4.	GND	GND (MPU-6050)
5.	GPIO 12	D0 (SW-420)
6.	GPIO 14	SDA (MPU-6050)
7.	GPIO 15	SCL (MPU-6050)

3. RESULTS AND ANALYSIS

Data from the test results in this research were obtained from five respondents with different gender, age, education level, and location of respondents during testing. This is to prove that the system can be easily used by users in many different places and many different backgrounds.

During the testing process, the prototype was placed on the edge of point-18 of the Lapindo Sidoarjo embankment for around 2 hours. After the researcher switched on the system (Switched on the voltage source), the researcher contacted the five respondents in turn. The respondents were asked to try each menu on the Telegram Bot, and at the end of the experiment, the researcher gave simulated vibrations and shifts in the field to find out the response of the system when something similar happened.

Figure 4. Prototype and its placement during testing.

During the test, the researcher recorded data results such as temperature, x-y-z axis positions, photos taken from each respondent, and the time required for each test. The results of this test recorded in two tables, Table 2 contains a record of the response system time, and Table 3 contains data received from the system.

Table 2. System response time test

Respondents	Request the menu first time	Request information on embankment condition	Request photo	Request photos with flash	Request a flash test	Get a message after vibration testing	Get a message after accelerometer testing
Responden 1 Shon, 23 tahun, College Student, 0 km distance with prototype	5 second	2 second	10 second	13 second	3 second	6 second	6 second
Responden 2 Aditya, 22 tahun, Employee, 20 km distance with prototype	1 second	3 second	12 second	10 second	5 second	6 second	3 second
Responden 3 Elsa, 17 tahun, High School Student, 7 km distance with prototype	3 second	3 second	10 second	8 second	4 second	7 second	6 second
Responden 4 Rachmad, 23 tahun, Freelancers, 14 km distance with prototype	1 second	2 second	12 second	11 second	6 second	7 second	7 second
Responden 5 Cindy, 22 tahun, Freshgraduate, 12 km distance with prototype	4 second	1 second	11 second	8 second	1 second	6 second	6 second

Table 3. Data received from thess system

Respondents	photo	photo with flash	SW-420 read vibration value	Flash testing	MPU-6050 read temp and axis positions	Axis position change after accelerometer test
Responden 1			On (1)	On (1)	Temp: 30.32 X-axis: -0.80 Y-axis: -0.36 Z-axis: 9.17	X-axis: -0.76 Y-axis: -0.12 Z-axis: 9.18
Responden 2			On (1)	On (1)	Temp: 31.31 X-axis: -0.79 Y-axis: -0.25 Z-axis: 9.17	X-axis: -1.32 Y-axis: 0.25 Z-axis: 9.21

Respondents	photo	photo with flash	SW-420 read vibration value	Flash testing	MPU-6050 read temp and axis positions	Axis position change after accelerometer test
Responden 3			On (1)	On (1)	Temp: 32.11 X-axis: -1.04 Y-axis: -0.16 Z-axis: 9.18	X-axis: -1.00 Y-axis: -0.60 Z-axis: 9.27
Responden 4			On (1)	On (1)	Temp: 31.92 X-axis: -0.61 Y-axis: -0.02 Z-axis: 9.21	X-axis: -1.23 Y-axis: 0.54 Z-axis: 8.97
Responden 5			On (1)	On (1)	Temp: 31.02 X-axis: -0.73 Y-axis: 0.24 Z-axis: 9.19	X-axis: -0.34 Y-axis: 1.47 Z-axis: 8.43

From the table of test results above, it can be analyzed that the distance of the respondent does not affect the response time of the system, the average of each test is as follows: Request the menu first time 2.8 seconds, Request information on embankment condition 2.2 seconds, Request photos 11 seconds, Request photos with flash 10 seconds, Request a flash test 3.8 seconds, Get a message after vibration testing 6.4 seconds, and Get a message after accelerometer testing 5.6 seconds. Besides that, Table 3 also shows that the system can run well, can capture photos every time they are requested, and can respond when vibration or plane shifts occur.

4. CONCLUSION

Based on the overall testing and analysis of the results above, the prototype of the Lapindo Sidoarjo Mud Embankment Leak Warning and Monitoring System can run well, indicated by each component being able to take readings and send responses back to the telegram bot. When there is a vibration or displacement in the embankment plane, the sensor will signal to the microcontroller and send warning messages to the telegram bot. Users can also get photos of the current condition of the embankment, temperature, and axis position when they request it. In this study, we know that distance does not affect the response time of the system. So we can implement the monitoring process anywhere, anytime, and the community can take mitigation actions if the system shows variables that can endanger the levee.

REFERENCES

[1] Direktorat Jenderal Sumber Daya Air, "Pusat Pengendalian Lumpur Sidoarjo," Surabaya, 2020.

[2] S. D. Ayuni, Jamaaluddin, and S. Syahrorini, "Strategi Mitigasi Bencana Tanggul Lapindo di Desa Gempolsari," *J. Teknol. dan Terap. Bisnis*, vol. 4, no. 1, pp. 8–11, 2021, [Online]. Available: https://jurnal.aksi.ac.id/index.php/jttb/article/view/95/58

[3] A. Ahfas, M. B. Ulum, D. H. R. Saputra, and S. Syahrorini, "Automatic Spray Desinfectant Chicken with Android Based on Arduino Uno," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 519, no. 1, 2020, doi: 10.1088/1755-1315/519/1/012013.

[4] D. Hadidjaja, A. Wisaksono, A. Ahfas, S. Syahrorini, and D. H. Untariningsih, "Bluetooth implementation on automation of Android-based gate doors," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1098, no. 4, p. 042061, 2021, doi: 10.1088/1757-899x/1098/4/042061.

[5] F. Susanto, N. K. Prasiani, and P. Darmawan, "Implementasi Internet of Things Dalam Kehidupan Sehari-Hari," *J. Imagine*, vol. 2, no. 1, pp. 35–40, 2022, doi: 10.35886/imagine.v2i1.329.

[6] K. Rose, S. Eldridge, and L. Chapin, "The Internet of Things (IoT): An Overview," *Int. J. Eng. Res. Appl.*, vol. 5, no. 12, pp. 71–82, 2015, [Online]. Available: https://crsreports.congress.gov

[7] Z. Arifin, "Meningkatkan Efektivitas Penanganan Gangguan Jaringan Internet Menggunakan Bot Telegram Dalam Mendukung Reliabilitas Komunikasi Data," *J. Algoritm.*, vol. 20, no. 1, pp. 148–155, 2023, doi: 10.33364/algoritma/v.20-1.1276.

[8] S. D. Ayuni, Jamaaluddin, and S. Syahrorini, "Sensor Accelerometer MMA7361 Sebagai Deteksi Getaran Pada Tanggul Lumpur Lapindo," *J. Teknol. dan Terap. Bisnis*, vol. 4, no. 1, pp. 31–36, 2021.

[9] M. Asri, S. Haisah, and S. A. Hulukati, "Penggunaan Jaringan Sensor Untuk Memonitoring Keretakan Pada Bangunan Berbasis Internet of Things," *J. INSTEK (Informatika Sains dan Teknol.*, vol. 6, no. 1, p. 110, 2021, doi: 10.24252/instek.v6i1.18643.

[10] M. Jamil, H. Saefudin, and S. Marasabessy, "Sistem Peringatan Dini Kebakaran Hutan Menggunakan Modul Nodemcu Dan Bot Telegram Dengan Konsep Internet of Things (Iot)," *KOMIK (Konferensi Nas. Teknol. Inf. dan Komputer)*, vol. 3, no. 1, pp. 1–5, 2019, doi: 10.30865/komik.v3i1.1558.

[11] A. Kurniawan, A. Narendro, R. A. Firdaus, and T. Wisjhnuadji, "Sistem Deteksi Lokasi Gempa Menggunakan Arduino Mega 2560, Sensor SW-420, GPS Dan Notifikasi SMS," *J. BIT (Budi Luhur Inf. Teknol.*, vol. 17, no. 1, pp. 62–68, 2020, [Online]. Available: https://journal.budiluhur.ac.id/index.php/bit/article/view/1016

[12] B. Firman, "Implementasi Sensor IMU MPU6050 Berbasis Serial I2C Pada Self-Balancing Robot Vol . 9 No . 1 Agustus 2016 ISSN : 1979-8415," *Juenal Teknol. Technoscientia*, vol. 9, no. 1, pp. 18–24, 2016.

[13] S. Ruswanto, E. S. Ningrum, and I. Ramli, "Pengaturan Gerak Dan Keseimbangan Robot Line Tracer Dua Roda Menggunakan PID Controller," in *The 13th Industrial Electronics Seminar 2011 (IES2011)*, 2011, vol. 2011, no. Ies, pp. 978–979.

[14] H. T. Permana, N. Soeharto, and A. W. Purwandi, "Sistem Pendeteksidan Monitoring Ruang Tahanan Menggunakan Sensor Getaran SW-420 Dengan Komunikasi LAN," *J. JARTEL*, vol. 9, no. 4, pp. 452–457, 2019.

[15] G. Swetha, "SP32 CAMERA," in *Intelligent Surveillance and Robotic Systems*, no. 3, 2023, pp. 7–11.

[16] W. Yulita and A. Afriansyah, "Alat Pemantau Keamanan Rumah Berbasis Esp32-Cam," *J. Teknol. dan Sist. Tertanam*, vol. 3, no. 2, pp. 2–10, 2022, doi: 10.33365/jtst.v3i2.2197.

[17] A. Isrofi, S. N. Utama, and O. V. Putra, "Rancang Bangun Robot Pemotong Rumput Otomatis Menggunakan Wireless Kontroler Modul ESP32-CAM Berbasis Internet of Things (IoT)," *J. Teknoinfo*, vol. 15, no. 1, p. 45, 2021, doi: 10.33365/jti.v15i1.675.

[18] A. Imran, M. Yantahin, A. M. Mappalotteng, and M. Arham, "Development of Monitoring Tower Using Gyroscope Sensor Based on Esp32 Microcontroller," *J. Appl. Eng. Technol. Sci.*, vol. 4, no. 1, pp. 405–414, 2022, doi: 10.37385/jaets.v4i1.1327.

[19] A. D. Mulyanto *et al.*, "Pemanfaatan Bot Telegram Untuk Media Informasi Penelitian," *J. Ilm. Komputasi*, vol. 19, no. 1, p. 49, 2020, doi: 10.32409/jikstik.19.4.336.

[20] A. Sanaris and I. Suharjo, "Prototype Alat Kendali Otomatis Penjemur Pakaian Menggunakan NodeMCU ESP32 Dan Telegram Bot Berbasis Internet of Things (IOT)," *J. Prodi Sist. Inf.*, no. 84, pp. 17–24, 2020.

BIBLIOGRAPHY OF AUTHORS

Shon Haji is currently a student in the Department of Electrical Engineering, Faculty of Science and Technology, Muhammadiyah University of Sidoarjo. He interested in technology and electricity since junior high school, choosing the electricity department in vocational high school, and now taking the topic of artificial intelligence as final project research in the university.

Akhmad Ahfas is an active lecturer in the Department of Electrical Engineering, Faculty of Science and Technology, Muhammadiyah University of Sidoarjo. He received a Bachelor's Degree from Muhammadiyah University of Sidoarjo and a Master's Degree from Technical High School of Surabaya. Some of the previous research he has done are: Line Tracer Robot Navigation System Using Arduino Uno Microcontroller with PID Control (2023), Innovative Document Sterilization Ultraviolet-C and Heating Approach for Effective Pathogen Elimination (2023), ID Cart as a Renewable Energy-Based Mobile Phone Charger (2022), and many more.

Syamsudduha Syahrorini is an active lecturer in the Department of Electrical Engineering, Faculty of Science and Technology, Muhammadiyah University of Sidoarjo. She received a Bachelor's Degree from Muhammadiyah University of Malang, a Master's Degree from Sepuluh Nopember Institute of Technology, and a Doctoral's degree from Brawijaya University. Some of the previous research she has done are: IOT-Based Sumo Robot Control Using Blynk Software (2023), Training on processing household organic waste into eco enzyme at 'Aisyiyah Sidoarjo Orphanage (2022), K-Nearest Neighbor Algorithm to Identify Cucumber Maturity with Extraction of One-Order Statistical Features and Gray-Level Co-Occurrence (2021), and many more.

Shazana Dhiya Ayuni is an active lecturer in the Department of Electrical Engineering, Faculty of Science and Technology, Muhammadiyah University of Sidoarjo. She received a Bachelor of Applied Science Degree from Surabaya State Electronics Polytechnic and a Master's Degree from Sepuluh Nopember Institute of Technology. Some of the previous research she has done are: Smart Shoe Care Enhancing Drying Efficiency and Material Preservation (2023), Accelerometer Sensor MMA7361 as Vibration Detector on Lapindo Lumpur Embed (2021), Measurement of Solar Cell Energy Effectiveness as a Power Source on Wireless Sensor Network (2018), and many more.